Sky and TELESCOPE

Palomar photograph of Jupiter

★

Vol. XII, No. 11

SEPTEMBER, 1953

Whole Number 143

★

In This Issue:

How to Estimate the Brightness of a Star

Galactic Star Clusters

Messier and His Catalogue — II

Stars for September

Sky and TELESCOPE

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The NSF and Astronomy

THE National Science Foundation was established to support research and education in a wide range of scientific disciplines. Since not all astronomers, and few of the educated astronomical public, are familiar with its operations, I would like to review briefly the organization and its activities this past year. This will also bring up to date the information in the note, "A Budget for Astronomy," *Sky and Telescope*, January, 1952.

Final decision on applications for research grants, support of publication, conferences, and fellowships are vested by the law in the National Science Foundation board; a permanent staff, in Washington, evaluates applications for final action. But in astronomy, as in most other fields, a panel of consultants has been established to advise the NSF on the scientific merits and relative value of applications for the limited funds. The panel has seven members: L. H. Aller, D. Brouwer, J. L. Greenstein, chairman, G. E. Kron, G. P. Kuiper, M. Schwarzschild, F. L. Whipple. Several new members will soon be appointed. An attempt is made to provide nationwide representation of both small and large institutions in this group and to represent the major fields in astronomy. Panel members are very conscious of the needs of the smaller institutions, and hope that they can assist the NSF in sponsoring a well-rounded development of astronomy in this country. Dr. Leo Goldberg, University of Michigan, represents astronomy on the divisional committee of the NSF.

In this first year, the operations of the NSF in astronomy have been on a small scale, because of a limited budget. The over-all appropriations have been only a quarter of the amount initially provided for in the law; rapid expansion will be necessary, because of the decreasing support of pure research by some of the military agencies. To date, the NSF has made eight grants totaling $89,000 for research projects in astronomy. Subjects cover the widest possible range, including stellar motions, galactic structure, the internal composition of the major planets, hydrogen-emission regions, orbit computation, and aid to the construction of a 24-inch reflector and a radio telescope. Both large and small institutions have obtained research grants: Chicago, Cincinnati, Harvard, Minnesota, Vanderbilt, Virginia, Wisconsin, and Yale.

Funds are given as a grant, rather than by contract. The equipment purchased becomes the property of the observatory or school. Red tape and accounting are at a minimum. Another feature of the grants is that funds have been usually supplied for a two-year period, and it is hoped that good-sized projects of even longer duration may be supported. Eventually, such government support of research will become more and more important. The NSF is still in an experimental stage, but we know that a satisfactory and efficient method of operation will be worked out.

Part of the program has been the financial support of technical conferences. Symposia with invited speakers, and limited attendance, have been or will be held on abundances of the elements, fundamental programs in astrometry, photoelectric techniques and instrumentation. The NSF-sponsored summer symposium at Michigan on galactic structure (announced in *Sky and Telescope*, April, 1953, page 156), was one of these. A solar energy conference at the University of Wisconsin is being held on September 12-14, at which about 30 physical scientists and engineers from this country and abroad will assess our present knowledge of solar energy utilization and point out needed areas for basic research. Motions in the earth's upper atmosphere will be the subject of a conference at the University of New Mexico, September 7th to 9th.

Some travel funds have also been supplied for attendance at meetings in Europe. Almost $27,000 has been so far granted for the conference program in astronomy.

A separate section of the National Science Foundation has responsibility for the spread of scientific information. Valuable support has been provided by a grant to the American Astronomical Society for the *Astronomical Journal*, the *Astrophysical Journal Supplements* (a new experiment in publication of longer papers), for the indexing of the *Publications* of the Astronomical Society of the Pacific, and for tables of eclipsing variables. The total support, to the extent of $14,000 thus supplied, is equivalent to the extra page charges for printing costs of about 1,500 pages of our technical journals. Publication of technical papers and monographs is expensive and slow; emergency help from the

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BACK COVER: The Double Cluster in Perseus, h and Chi Persei, photographed with the 36-inch Crossley reflector, October 22, 1939, two-hour exposure with the aperture reduced to 24 inches. West is at the top. Lick Observatory photograph. (See page 292.)

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How to Estimate the Brightness of a Star

By Sergei Gaposchkin, *Harvard College Observatory*

FROM my temporary office in Pasadena, against a background of scrubbed mountains and hazy twilight there are silhouetted several tall, slender palm trees. I lead a friend to the window, and, selecting three curly palm heads which to my imagination appear exactly like those amorphous, heavy blobs on photographs which we call star images, I ask him to estimate the brightness of a palm head relative to two others, one darker, the other lighter. Amazed, my friend looks alternately at me and at the palms, with a bewildered expression. To relieve his embarrassment, I say promptly, "Forget it, it's a mystery."

Yes, estimation of the brightness of a star is a mystery. And if you know that you have neither that inspired artistic touch nor the illuminating inner spark that makes a person a reliable observer, you have no recourse but to get an expensive photometer. Fortunately, however, most people have these two requirements, though naturally in very different degrees. That is why estimations by primitive man are still valid and why the ancient Greeks, some 2,000 years ago, could initiate one of the most fascinating fields in astronomy—the magnitude system.

Let us limit ourselves to the specific case of estimating the brightness of a variable star, since variables yield results of the greatest importance to astronomy and will always remain on the front line of research. While we will take our examples from the estimation of star images on photographs, everything discussed here will be directly applicable to visual observations of the stars themselves.

There are two idealized methods of estimation, which contain all the others as variations, and which I shall call the *step* and *fraction* methods. The step method can be summarized by saying that the observer tries to acquire a sense of blackness (of the star images on a negative) by having a mental picture of units of blackness, and the smallest unit would be the observer's "step."

How can the art of estimating by steps be attained? There have been many astronomers who have worked with steps and have gotten excellent results. Perhaps you have sometimes seen the following practical suggestion for comparing two stars of similar brightness: If you can say, "They are equal; no, *a* is brighter; no, *b* is brighter; no, they are equal," then you have your zero step. But if out of six looks four favor *a* as the brighter, then you have your first and basic step. From here on it is easy. You pile together steps so that you judge the interval between the two stars to be one, two, three, four, five, or six steps. Beyond six you proceed very cautiously, if at all.

How large is the step, that renowned weapon of so many celebrated astronomers? It is different from person to person, and depends much on conditions and on the material with which you work. Some workers assert that the step can be as large as 0.3 or as small as 0.04 magnitude. Personally, I do not believe in such extremes; my step value on plates of the Harvard collection is about 0.08 over the magnitude interval 8.5 to 12.5. For most observers, the step is near 0.10 magnitude. But the quality of the plates can cause some surprises. For example, on photographs taken with the 100-inch Mount Wilson telescope, my step was often only 0.04!

Proficiency in the step method is not difficult to attain. But when you have acquired some skill, it is all too easy to trust your step value too literally, and to act as if you had a self-recording photometer built into your head. There is the temptation, if your steps do not agree with the comparison star magnitudes, to change the magnitudes. This mistrust of magnitude and confidence in steps is at least partly due to the great difficulty, prior to the photoelectric era, in setting up reliable standard magnitudes. Even

A map of the north polar sequence stars, such as this one for the visual magnitude range 4.37 to 9.87, would be used by a visual observer working with the author's method of brightness estimating. For fainter stars in the sequence, the AAVSO has additional maps on a larger scale, centered around the pole. Reproduced courtesy American Association of Variable Star Observers.

today, we have not more than three or four fully proven standards of magnitude.

Some astronomers, distrusting the subjective nature of the step scale, have followed the fraction method, in an effort to obtain a less personal approach. While the "steppist" places the variable in his comparison star sequence with the aid of his step value, the "fractionist" interpolates the variable fractionally between two comparison stars, usually by tenths of their interval. Such fraction estimates are quite easy to make.

The method used by the American Association of Variable Star Observers is a simplified fraction method. For example, an AAVSO observer, noting that a variable is brighter than an 8.5-magnitude star but fainter than another of magnitude 8.0, may judge that calling the variable 8.2 will properly divide the interval between the comparison stars. Note, however, that the AAVSO observer uses comparison star magnitudes determined for him beforehand, thereby by-passing an essential task of the astronomer-estimator.

Both steppists and fractionists pay much attention to the comparison stars before estimating. This is particularly necessary for the fractionist, as he is at the mercy of their adopted magnitudes, and cannot check them by his method. In the fraction system, no account is taken of the actual difference between the comparison stars, the number of subdivisions used for estimating being the same regardless of the actual magnitude range involved. The steppist, however, takes this difference into account while making his estimate. I remember that the late Dr. Richard Prager used to urge that the steppist always write down the differences in steps between the comparison stars for every plate investigated. If you are estimating a variable on only a few dozen plates, there is little difference in the time required by the two methods, but when a million observations are involved, as in a program which confronted me, a steppist would need several lifetimes to finish the job.

Both methods are of the same intrinsic accuracy, and both have yielded important astronomical results and discoveries. While a photoelectric observation is considerably more accurate than a skillful estimate, this fact is often misinterpreted, and often the photoelectric observer views estimates with a supercilious antagonism. On the other hand, occasionally one hears an irreconcilable steppist say, "Hardly anything of importance has been found about variables photoelectrically which has not already been found by estimators." The truth lies between these extreme attitudes. When observations of the highest accuracy are required, and justify expenditure of much time and effort, there is no substitute for photoelectric photometry. But for survey work, the determination of periods and types of the thousands of recently discovered faint variables, the vastly greater speed and ease of estimates leave no room for competition. Using the Harvard collection of photographs, I can within two days trace the past history of a new variable star for the last half century, but to get a similar record would take a photoelectric observer 50 years!

My own method of estimating differs from both the classic step and fraction techniques. In essence, step estimates are used to establish a comparison star scale, once and for all, and then the variable is interpolated into this scale fractionally. In 1935, soon after I came to Harvard Observatory, I was confronted with a mammoth undertaking of estimating a thousand variables on a thousand plates for each. From my previous work, I knew of both methods—both are attractive and ordinarily they are of equal accuracy. But one feels less secure during the process of fractional estimates, while the difficulty in acquiring a stable step value makes that method less secure too.

The step method does have an obvious advantage, not in procedure or accuracy, but in reducing the observations. When you have finished making the estimates, you would like to show definite magnitudes, but very often you do not have magnitudes for the comparison stars, or else their magnitudes are so uncertain that it is best to leave them untouched. In either case, the fractionist cannot proceed further, but the steppist can go on to find the period and obtain the light curve—which is the final goal of a variable star observer.

The first part of my method is learning to estimate in units proportional to the blackening of the star images. I began by studying plates of the celebrated sequence of standard magnitudes, the north polar sequence (NPS). Between each pair of stars I inserted mentally the number of units proportional to the difference in blackness of the star images. If the difference was about one magnitude I assigned 10 units; if about a third of a magnitude, three units; and so on. In particular, I made no effort to acquire a step such as was described earlier. I was not concerned whether I had put exactly the right number of units between the north polar sequence stars, but what did matter was that on the average I saw a direct proportionality between the increase in blackness of star images on the plate and the number of units.

This was found to work very well indeed when I explored on Harvard plates the variations of stars in the magnitude interval between 8.0 and 13.0, which is usually on the steep straight part of the S-shaped sensitivity curve of the plates. I have never forgotten the bright north polar sequence stars, because they are old friends. But still at intervals I go back to these stars, look at them and verify my unit, so to speak. This check has always been satisfactory.

Incidentally, there are well-known pitfalls in estimating very strong or very weak images on photographs, pitfalls which were clearly shown on the north polar sequence plates taken with different instruments or with varied exposures. Even so, after long experience one becomes brave enough to estimate stars of the 2nd magnitude or even brighter on plates where there are only one or two similar stars for comparison. Such heroic measures can be demanded by bright novae.

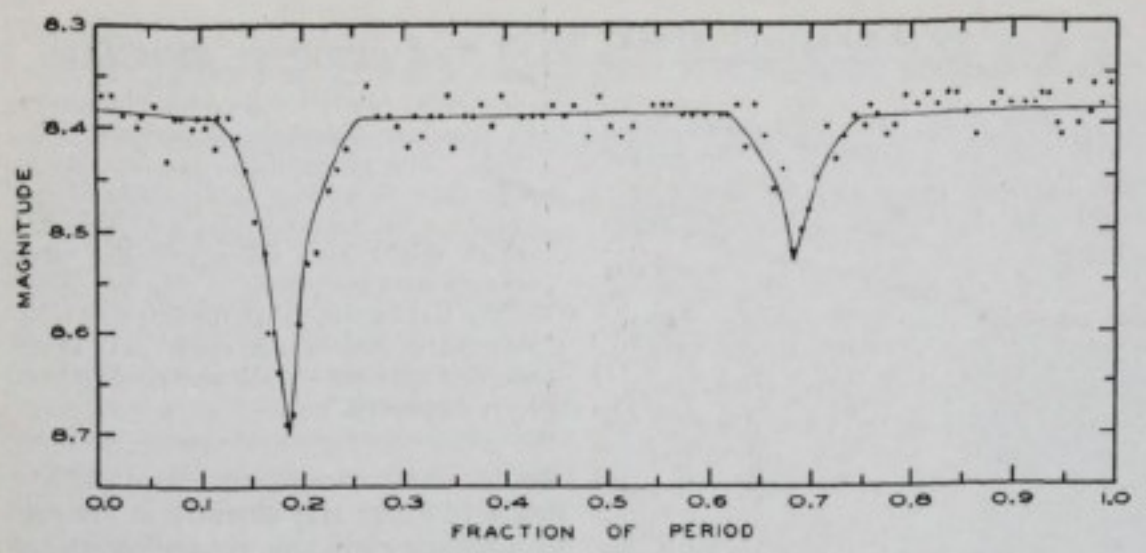
The second part of my method is applied to the field of a particular variable. Usually I employ between five and 10 comparison stars. To avoid unpleasant surprises later, they are first investigated for variability. Then, based on my experience with the north polar sequence, I assign the number of my units for the interval between successive stars. I take the average of each interval from six or eight plates and round off the mean to the nearest integer. Then I add all the steps together, piling them from the faintest star to the brightest. My most reliable intervals (in blackness, not magnitude) are 3, 4, 5, or 6; intervals of 7 or 8 are less trustworthy; and intervals of 1, 2, 9, 10, or 11 are undesirable. Thus, I now have a scale expressed in numbers, from 0 to 30 for example, pinned to the comparison stars, from the lightest to the blackest one.

The third part of my procedure is to estimate the variable's brightness. Suppose the variable is intermediate in brightness between comparison stars *b* and *c*. I interpolate it *not by steps* but fractionally, asking myself in what ratio the variable divides the interval *b* to *c*. First I ask: Is it

HV 11111 = V444 Cyg

Star	Step Scales from individual plates										Adopted	Magnitude
a	6	8	75	65	7	7	7	7	9	7	70	8.36 ± 0.04
b	4	5	6	4	3	6	7	5	5	5	Omit	— —
c	35	3	35	4	3	4	4	3	3	35	35	8.45 ± 0.06
d	0	0	0	-1	0	0	1	1	0	0	0.0	8.72 ± 0.05
d'	-1	-2	-1	-2	-1	-3	-2	0	0	-2	Omit	— —
e	-6	-7	-6	-6	-6	-5	-6	-7	-6	-7	Omit	— —

A sample working record shows how the comparison star scale was set up by Dr. Gaposchkin for the variable star V444 Cygni.



This photographic light curve of the eclipsing variable star V444 Cygni is based on the author's estimates on 1,084 Harvard Observatory plates. Each point is the mean of 10 observations, on the average.

equal to either *b* or *c*? If not, then is it halfway between? If it is neither of these, I try thirds, quarters, or fifths. Usually, I do not attempt to subdivide the interval closer than to fifths, as I do not believe the human eye can go finer with any sureness. To avoid having to do this, if an interval is larger than about eight units I try to find an additional comparison star to fit into the gap.

All of my estimates are made rather quickly, with only a few seconds deliberation. If you labor too long on fitting the variable between the comparison stars, you lose accuracy and tire quickly. You should be relaxed physically but not mentally. You place the variable between the comparison stars; you interrogate its relation to their blacknesses; you wait for a second; and then comes a brief moment of a high degree of spiritual concentration—and you know the value for the star.

My method has advantages over both the pure step and fraction procedures. The fractionist is in trouble if the interval to be divided is too small, or if it varies, or if he has to drop one of his comparison stars. I can replace a recalcitrant comparison star at any stage with another more suitable, without having to throw out numerous previous estimates. I also by-pass the most troublesome part of the step method, which is keeping the elusive step invariable in value. Once my scale of units for the comparison stars has been set up, I have no further concern with step value.

The most important advantage is an enormous saving in the work of writing down the estimates and reducing them. The temporary steps are exceedingly flexible and lend themselves readily to lengthy computations, since they are expressed in only one or two digits, while magnitudes are usually expressed in four. Not only is labor saved, but there is greater security against errors. Only by this method could we finish within a decade the Harvard survey of bright variables, which required the accumulation and discussion of two million photographic observations. Dr. Prager predicted that this program, by the classical methods, would be finished in A.D. 2000. I think his prediction was optimistic!

For this project I had several assistants who learned the method quickly and easily. I did not send them all the way back to the north polar sequence, but gave them comparison star scales I had worked out. Some of these assistants soon surpassed their teacher, which I think natural and good.

As an example of the use of my method, I mention two eclipsing variables. The discovery of eclipsing systems has usually been made by a random inspection of plates taken at different times, which yields variables with large amplitudes, that is, with large ranges of brightness between maximum and minimum. On the other hand, I have been able to find such remarkable eclipsing systems of small amplitude as V444 Cygni. This star had been announced previously as nonvariable. In 1940 I employed basically three comparison stars, although a few others were also of use. The table on page 284 shows the actual estimates on my own scale. The stars *b*, *d*', and *e* have been abandoned as not suitable, and they were used only as checks.

The magnitudes were determined from an accumulation of over a thousand observations. The mean range of the variation was from 4.7 to 0.3 of my units for the primary minimum and from 4.7 to 2.4 units for the secondary minimum, which was equal to 0.31 magnitude change (8.39 to 8.70) for the first and 0.14 magnitude (8.39 to 8.53) for the second. Later the photoelectric observations at Lick Observatory exhibited ranges of 0.30 and 0.14, respectively.

A famous eclipsing variable with a long period is the 3rd-magnitude star Epsilon Aurigae (see *Sky and Telescope*, February, 1953). Since the range of this variable is much larger than that of the previous system and it lies on the bright end of the sensitivity curve of the plate, I have used more comparison stars and my step unit is smaller. In 1941, I discovered on Harvard plates the 1901 and 1928 eclipses of this system. For the former I obtained a range of 19.0 to 5.5 and for the latter 18.5 to 4.0, both in my step units. Thus, on the average the amplitude of both minima is 14 steps, or expressed in magnitude, about 0.80. It is well known that the photoelectric observations of the eclipse of 1928 resulted in an amplitude of 0.80 magnitude.

All observers should be aware of the impending eclipse of Epsilon Aurigae in 1955-56, which fortuitously coincides with an eclipse of another most fascinating system (established as an eclipsing variable by this method also), the supergiant VV Cephei. What an adventure astronomers all over the world will have in the next few years!

THE NSF AND ASTRONOMY

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foundation will be very useful in coping with our serious publication problems.

Support of graduate students and young astronomers is provided in two important ways. They often do work as assistants in the research projects. Also, the NSF has both pre- and post-doctoral fellowships, of which 11 have been given to promising young students of astronomy. In the past, for many astronomers, freedom from routine work and the opportunity for travel to a new institution were given by the National Research Council fellowships. With the extension of the NSF program, we can look forward to wider availability of such valuable, often decisive, periods of generous aid for the astronomers of tomorrow.

The program is still small compared to the needs of modern astronomy, but the NSF cannot spend more than a fraction of its funds in our (numerically) small field. With the expected expansion to the full budget, astronomy can look to the NSF for support of pure research, the construction of new facilities, modernization of old ones, aid in the publication of monographs and journals, fellowships, and conferences. These aids are particularly important when inflation and the disappearance of the individual donor have actually cut the staffs of many of our large observatories and closed down many small astronomy departments.

We hope that the astronomical community will support the NSF and assist it in trying to understand the needs and problems of astronomers. If Congress grants its full annual appropriation (15 million dollars in the original bill), the impact of the National Science Foundation on science will be very great.

JESSE L. GREENSTEIN
California Institute of Technology

NEWS NOTES

By Dorrit Hoffleit

THE NEXT SUNSPOT MAXIMUM

According to a recent prediction by S. W. Visser, of Utrecht, Holland, the coming sunspot maximum will occur in 1959. He points out, in the June *Journal of Meteorology*, that the extreme peaks of the sunspot curve do not give the true period of the sunspot cycle; it is better to take the middle of the three consecutive years of highest activity as the date of maximum, a method proposed by Mecking in 1939. When this principle is applied to past sunspot observations, the 11-year cycle becomes much more regular. The last maximum, defined in this way, was in 1948, instead of in 1947.

Using sunspot data since 1750, Visser finds some indication of an 89-year periodicity in the heights of sunspot maxima. If this periodicity is real, the approaching maximum should be a strong one. The 89-year period matches one found by Easton in 1917, deduced from the behavior of winter temperatures in western Europe starting with the year 1205.

ANCIENT MASSIVE STARS

The "deaths" of large numbers of massive, fast-living stars that were formed in the very earliest stages of our galaxy may be the cause of the present high frequency of white dwarf stars as well as of the heavy elements that are so abundant in the relatively young stars of Population I. This "entirely hypothetical" proposal is made by Martin Schwarzschild and Lyman Spitzer, Jr., of Princeton University Observatory, in the April issue of *Observatory*.

The stars of Population II (such as compose the nucleus of the galaxy) have generally only a third and sometimes only 1/10 of the metal content of Population I stars (in the spiral arms). Since the extreme Population II stars are presumably the oldest, our galaxy may have had in the beginning only 1/10 the metal content that the Population I stars now have; these metals—relatively heavy elements—must therefore have originated since the formation of the galaxy and after the first stars were formed.

The white dwarfs, except for their thin atmospheres, must be virtually hydrogen-free, and presumably could not have formed out of interstellar material consisting predominantly of hydrogen. If, however, white dwarfs are the end products of the deaths of highly luminous stars (occurring as supernovae), the present mortality rate is far too low to account for the estimated three billion white dwarfs in the galaxy.

On the assumption that both the heavy elements and the white dwarfs are the results of such massive-star deaths, Schwarzschild and Spitzer suggest that heavy stars may have been much more common in the early days of the galaxy than they are now, and the death rate might well have been a hundred times greater.

Applied elsewhere in the universe, this proposal may also explain the excessive redness of the more distant (younger) elliptical galaxies when compared to spirals at the same distance, an effect found by Stebbins and Whitford several years ago. The ellipticals contain Population II stars only; no new stars appear to be born, and the deaths of the originally numerous massive stars would result in significant changes with age in the colors and brightnesses of the elliptical systems.

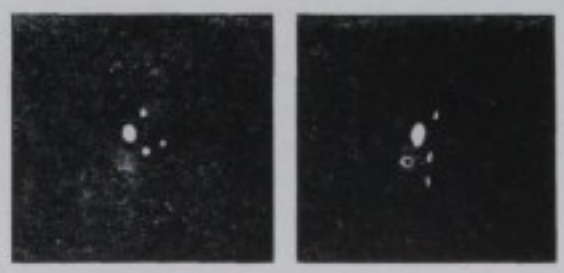
A RADIO SOURCE AND A CHINESE SUPERNOVA

It is known that the Taurus radio source coincides in position with the Crab nebula, the remnant of a galactic supernova recorded in the Orient in A. D. 1054. This suggested to the Russian astronomers, I. S. Shklovskii and P. P. Parenago, that further comparisons of the positions of radio stars with old records of novae should be made.

One of the most intense radio sources is in Cassiopeia at $23^h\ 21^m.2$, $+58°\ 32'$ (1950), where Dewhirst and Baade have photographed faint nebulosity. The Russians find that this is in a region where Chinese astronomers observed a new star for six months in the year 369. While the ancient record of this object is brief and vague, it appears to indicate a supernova rather than an ordinary nova.

ELECTROPHOTOGRAPHY

Electron telescopes have been proposed for many years, but none had been developed to equal the definition obtained by optical instruments. Now, in France, André Lallemand and Maurice Duchesne have developed an electronic image-amplifying apparatus that has been used successfully with the 26-centimeter coude telescope at the Paris Observatory. At f/40, pictures showing Saturn with good definition were obtained in only 1/5 second, while the ordinary photographic method required 10 seconds for comparable results. For the quadruple system Theta Orionis, an electronically produced image was obtained in five seconds showing all four components more clearly than an ordinary three-minute photograph (see the illustration).



An electronic photograph of Theta Orionis (left) and an ordinary picture. Reproduced from "Comptes Rendus."

During World War II, infrared and ultraviolet image converters were developed for military purposes. These work on the principle that radiation striking a photosensitive surface, such as cesium oxide, causes the release of electrons. These, in turn, can be accelerated and focused by a strong electric field until they fall on a second surface, there creating either a visual image or exposing a photographic plate. Blackening depends only on the total charge transferred; thus the exposure by electrons is not subject to reciprocity failure and the faintest source of light can be detected if the exposure is made long enough. And although the present best photocathodes are not more than 20 per cent efficient, the gain over direct photography is enormous, as the exposure times mentioned above indicate.

Lallemand and Duchesne used the telescope to focus starlight on a cathode plate which ejected electrons. These electrons were accelerated in a field of up to 30,000 volts and refocused electrostatically on an ordinary photographic plate at the anode. But the tube containing these parts had to be kept at a vacuum continuously because photosensitive surfaces are destroyed on contact with air. The cathode, a 25-millimeter glass disk coated with a cesium-antimony film, was prepared in a thin vial and mounted in the main tube. The latter was evacuated before a magnetically operated hammer was made to break the vial, leaving the exposed cathode in proper position with respect to the electron lens. The magazine containing the photographic plates was also magnetically operated, in order that plates could be changed without losing the vacuum. Refrigeration by liquid oxygen was also necessary. With all these precautions, however, the inventors warn that the apparatus is still in the experimental stage, for it is difficult to maintain the vacuum very long in the presence of the almost inevitable contaminating influences of the photographic plate.

The French scientists describe their apparatus and experiments in *Comptes*

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IN THE CURRENT JOURNALS

IS MAN ALONE IN SPACE? by Loren C. Eiseley, **Scientific American**, July, 1953. "The probabilities are less favorable than they may seem. Man is not simply a matter of a throw of the dice which might have fallen just the same way on another planet. . . . At any point in the last billion years the line of evolution that produced man might have taken another turning — and we would never have appeared."

Amateur Astronomers

The Development of a Student-Amateur Observatory

SEVERAL years ago, a Sacramento daily newspaper carried a story that began:

"The dream of an amateur astronomer who started with nothing but an idea and ended up with an observatory worth in the neighborhood of $20,000, having a 12½-inch reflector telescope, does not prove the old adage of all things coming to him who waits."

The story related how a young student of the Sacramento Junior College, Henry Hughes, thought it would be a good idea for the college to have an observatory and carry a course in astronomy in its curriculum. He was himself very much interested in the subject, and several other students shared his desire to know more about the worlds in the sky.

Hughes and his friends began by constructing a model of the proposed observatory building. He took it to the college regents and asked their authority to initiate its construction as a work project of the engineering department. He undertook to obtain materials the college could not supply, and he and his associates agreed to contribute their time and labor. Here was an innovation, and the faculty agreed that his enterprise should be encouraged.

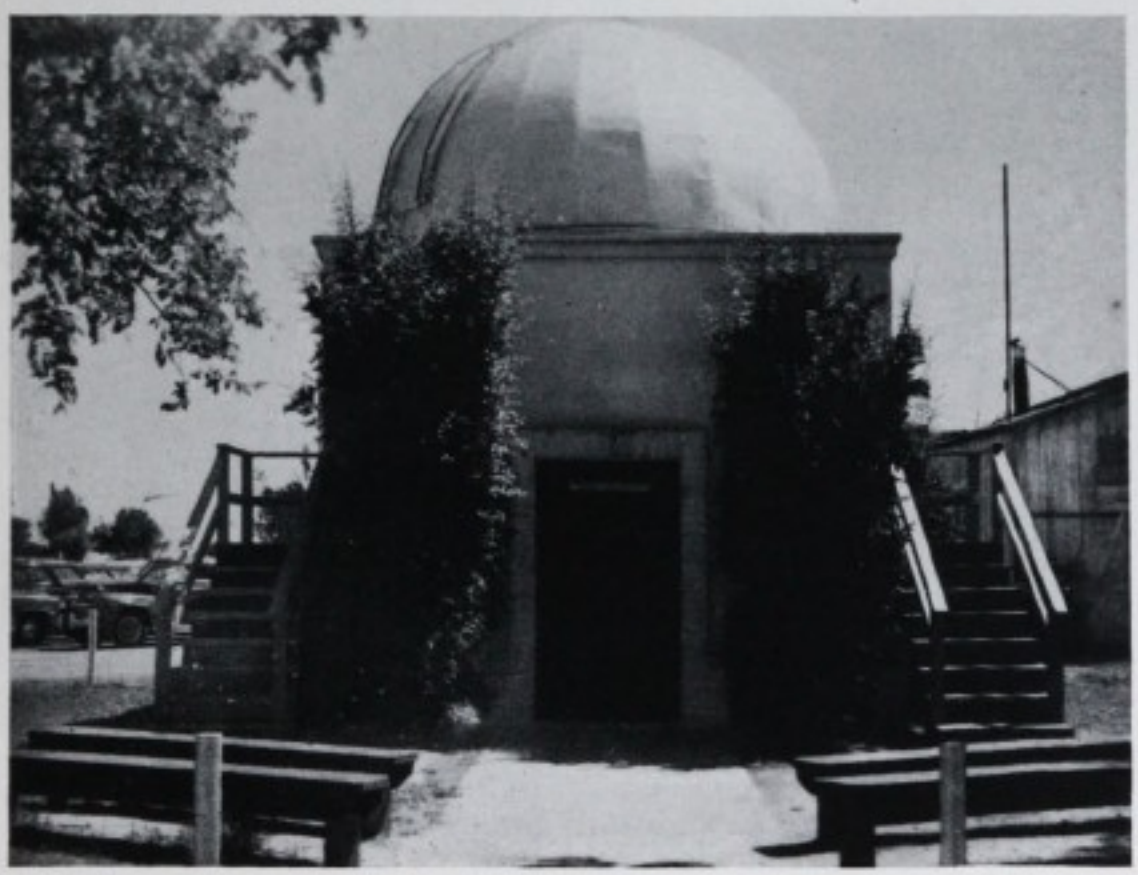
A suitable site on the college campus was obtained. Bricks and lumber were recovered from some old abandoned school buildings, and some government works projects aid of the depression era was utilized. In addition, Hughes raised 75 dollars by an appeal to the student body. The two-story structure is 20 feet square, the 15-foot dome rising from the second floor. A concrete pedestal from the ground to the level of the second floor provides the telescope pier. A small darkroom, office, book shelves, and space for tools and storage were provided in the plans.

A local automobile dealer arranged to lend his 9-inch Newtonian reflector to the college, and also contributed a sidereal clock. All was about in readiness for putting the observatory into operation when in the spring of 1937 a severe storm took the dome off and deposited it on the front lawn of a nearby house! A new steel dome was made in replacement, and the observatory opened in September of that year. The first director was the observatory's student creator, Henry Hughes, who presided over its destinies until he graduated.

Classes in astronomy were started and students began making regular observations. On December 2, 1937, the first photographs taken with the instrument were made of the partial eclipse of the sun. These pictures were used by all the Sacramento daily newspapers, and their publicity "put the observatory on the map." The records show that in the

(Continued on page 294)

A corner of the office of the Sacramento Junior College Observatory. Photographs by Victor W. Killick.



The observatory of Sacramento Junior College, showing the dome of the 12½-inch reflector and the new benches and stairways that provide efficient facilities for handling large crowds of visitors.

BURNHAM SOCIETY SPONSORS LARGE TELESCOPE

A 24-inch Newtonian reflecting telescope to be housed in an observatory building on the outskirts of Chicago, financed by public contributions, is a current project of the Burnham Astronomical Society. The f/8 pyrex mirror of the instrument will be figured by members of the mirror making division of the society.

While the telescope will be primarily for scheduled research work and observations by society members, it will be available to the public on visitors nights, and for observing special astronomical events such as eclipses, comets, novae, and so on.

The Burnham Astronomical Society meets at Chicago's Adler Planetarium the second Sunday of each month from October to May. Officers are Russell Anderson, president; Frank L. Goodwin, vice-president; Frieda Rahn, secretary; and Andrew Hay, treasurer.

FRANK L. GOODWIN
345 Belden Ave.
Chicago 14, Ill.

THIS MONTH'S MEETINGS

Dallas, Tex.: Texas Astronomical Society, 8:00 p.m., Lone Star Gas Co. auditorium. Sept. 28, anniversary meeting; election of officers.

Indianapolis, Ind.: Indiana Astronomical Society. Sept. 6, observation meeting, Butler University.

Kalamazoo, Mich.: Kalamazoo Amateur Astronomical Association, 8:00 p.m., home of Dr. and Mrs. L. N. Upjohn, 1556 Long Rd. Sept. 19, Dr. Upjohn, "The Star Clock."

MESSIER AND HIS CATALOGUE--II

BY OWEN GINGERICH, *Harvard College Observatory*

MORE AND MORE frequently in the 1780's a new name appeared in the annals of comet discoveries. Charles Messier, whose indefatigable observations had earned him the title of "ferret of comets" from Louis XV, found keen competition in a younger astronomer at the Marine Observatory, Pierre François André Méchain. It would not be surprising to discover a strong jealousy between these rivals. Yet, if it existed, biographers have remained silent. We can only deduce that the two were professional acquaintances, freely sharing their data. Several times Messier recorded that "Méchain informed me of the discovery [of the comet] the following day." Their careers have so many points of contact that any biography of Messier must also be an account of Méchain.

Born August 16, 1744, in Laon, Méchain was slightly over 14 years Messier's junior. As a boy, he studied mathematics and physics as well as architecture, his father's profession. Méchain later went to Paris, to the leading architectural school. But financial difficulties beset his father, and to raise funds Méchain's astronomical quadrant was offered to the astronomer Lalande, who immediately became interested in the young man who had purchased it in his desire to study the heavens.

After an interview, Lalande agreed to teach Méchain astronomy, and assigned him the proof sheets of the new edition of his *Astronomie*. When Lalande visited him shortly thereafter, he was astonished at Méchain's progress in the most difficult astronomical mathematics. In 1772 Lalande procured Méchain a position of astronomer-hydrographer in the naval map archives (Depôt de la Marine) at Versailles. But the position was uncertain, because of the political unrest in the French government, and Lalande obtained for him employment as a tutor. Eighteen months later the entire department was reorganized, and Méchain returned to his old position. Soon thereafter the Depôt was moved to Paris, where, if not before, Méchain must have met Messier, who was well established as Marine Astronomer. Méchain's work called him away from Paris much of the time, however, as he was mapping the French coast line.

Meanwhile Méchain had turned his eyes to the heavens, and in 1774, while still at Versailles, he observed an occultation of Aldebaran. Lalande introduced Méchain to the Academy of Sciences by presenting a report of the observation, which was later printed in the memoirs. In 1781, Méchain discovered two new comets; in addition to observing them, he calculated their orbits. The following year the academy awarded Méchain a prize for his essay on the comets of 1552 and 1661. A return was expected in 1789, but he showed that these were two separate comets, neither of which would return that year. Such theoretical work was typical of Méchain, and calculations as well as observations were generally included in his comet memoirs. Thus the mere discovery of about 10 comets, including Encke's and Tuttle's, represents only a small part of his efforts. Méchain was soon recognized for his work, and in 1782 he became a member of the academy.

During his comet searches in 1780-81, Méchain discovered about 32 new nebulous objects. Appropriately, these discoveries were communicated directly to Messier, who checked their positions in the course of his own observing, but not always in their original order, so for a further extension of the catalogue each one was numbered as Messier observed it. He generally followed up Méchain's observations several weeks later, but as the deadline for the 1784 *Connaissance des Temps* approached he confirmed them within a few days. Apparently Méchain first realized the abundance of nebulae in the Coma-Virgo region. On March 18, 1781, Messier followed up the lead with a busy night, recording nine new nebulae in the area. Ironically, one of these, M91, has never been since observed.

Nearly 20 degrees south of Spica, along the southern boundary of Hydra, lies M83, a striking spiral galaxy which is about six million light-years from the solar system. Harvard Observatory photograph.

Messier's contemporary Pierre Méchain (1744-1805), from a portrait in the "Monatliche Correspondenz," 1800, edited by Baron F. X. von Zach.

The veteran comet observer may have been hoodwinked by a real comet!

Messier made his last catalogue observation on April 13, 1781, only a year after his final work on the 1780 addition to his original list. This brought the total number to 100, with 24 of these additions credited to Méchain. Unfortunately, Messier had no chance to check three of Méchain's observations, or positions for two more objects in Ursa Major noted with the description of M97 (see the quotation later in this article), before publication of this list (in 1781). Nevertheless, he attached Méchain's observations to the end as 101, 102, and 103, although no positions were given for the latter two. Thus, 35 new objects and descriptions were added to the previous 68, and the earlier descriptions were slightly extended to cover more recent observations.

Further revision of the catalogue was abruptly terminated by a severe accident to Messier. In November, 1781, he visited the garden of Monceau with his friend Bochard de Saron, president of the French Assembly. Messier's attention was attracted by a door which he assumed led to a grotto. Instead, it was an icehouse. Entering without precaution, he fell 25 feet onto the ice, breaking his arm, thigh, wrist, and two ribs. Fortunately, someone noticed with surprise that the icehouse door was open. Three men with ropes and ladders finally removed him, and the astronomer was placed under the attention of the most skilled academy surgeons. Messier, always an empirical observer, disliked the theory and art of the surgeons, especially when

Valdajou rebroke his thigh to set it better!

President Saron and the other academicians were especially solicitous during Messier's illness. A Monsieur Sage obtained a royal grant of 1,200 livres for him, followed by a pension of 1,000 livres and another gift of 2,400 livres. President Saron, incidentally, was well known for his exemplary generosity in science, and was an accomplished mathematician. He was among the first to realize, by computing its orbit, that Uranus was a new planet.

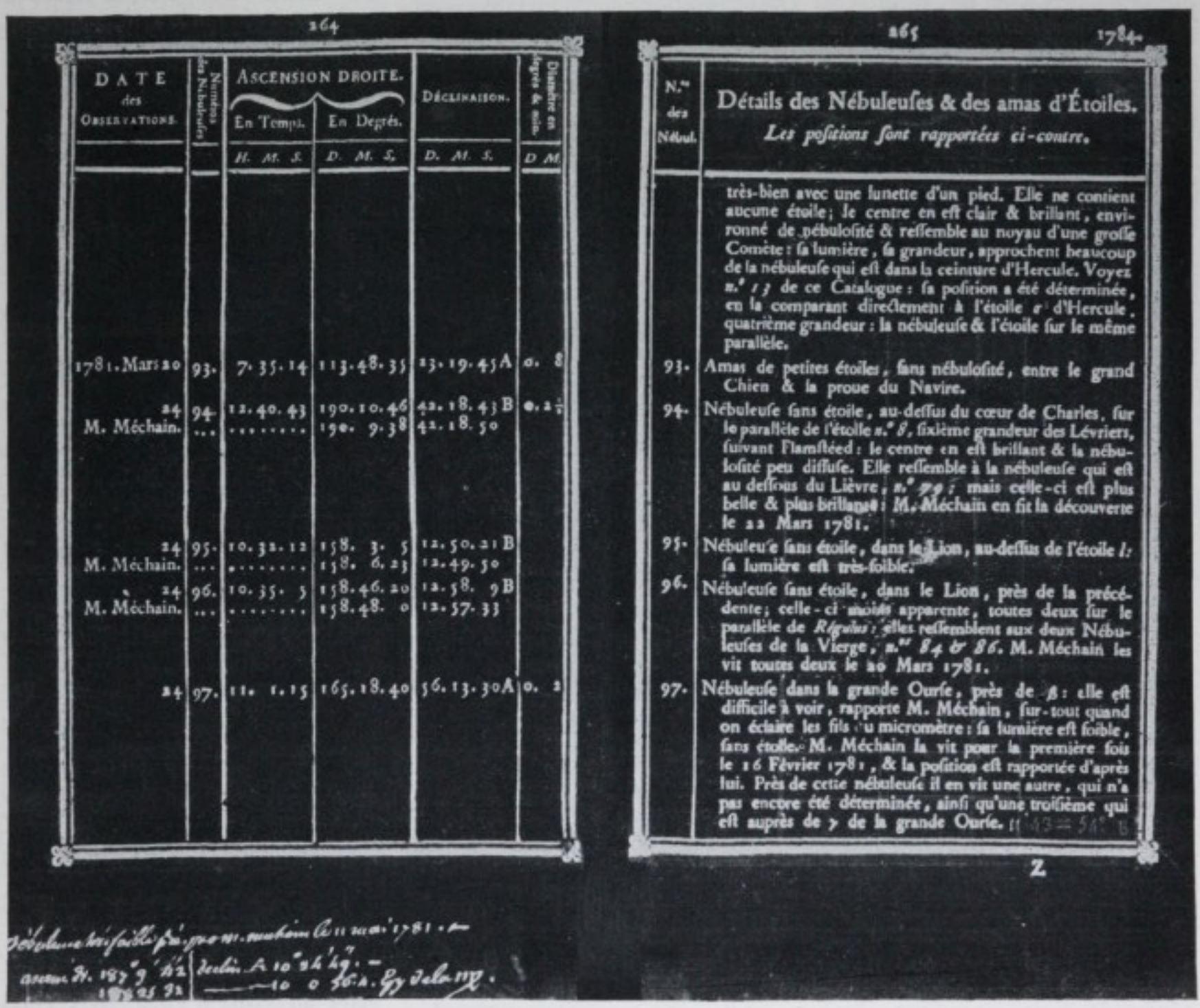
One year and three days after his fall, Messier again entered his observatory, to prepare for a transit of Mercury. Soon he resumed his observations of Herschel's new planet that had been interrupted by the accident. His tireless watch of comets, eclipses, and transits began again.

Further work to extend the catalogue of nebulae and clusters was also planned, although in 1784 the previous list was printed exactly (in the *Connaissance des Temps* for 1787), including most of the same typographical errors. As before, no positions were given for M102 and M103, and hence later observers sometimes did not include them in Messier catalogue lists. In 1783, for instance, the German almanac, Bode's *Berliner Astronomisches Jahrbuch* for 1786, published a list of the objects from M46 to M100 with positions determined by Messier, and in Bode's *Uranographia* (1801) only the initial 100 appeared.

The list in the *Astronomisches Jahrbuch* was evidently communicated by Méchain, for those objects discovered by him are indicated, information not specifically tabulated in the French edition. In addition to the catalogue of nebulae and clusters, a letter from Méchain appears later in the book, in which he announced that through an error in the chart M102 was tabulated, though actually identical with M101. Until this letter was brought to notice, just recently,* there was considerable confusion in attempted identifications of M102. With the correction, he also included the descriptions of six new objects. Four of these had been found too late for inclusion in the 1784 *Connaissance des Temps*. Positions were given for three of them, while the descriptions suffice to locate the others.

Undoubtedly Messier was aware of the new discoveries almost as soon as they were made. Evidence is found in his personal copy of the printed list, now owned by Mme. Camille Flammarion. A handwritten note at the bottom of a page indicates another nebula in Virgo, one of the four new ones reported by Méchain in the *Jahrbuch*. Several other

*Helen Sawyer Hogg, **Journal**, Royal Astronomical Society of Canada, 41, 265, 1947.



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DATE des Observations.	Numéros des Nébuleuses	Ascension droite. En Temps. H. M. S.	Ascension droite. En Degrés. D. M. S.	Déclinaison. D. M. S.	Diamètre en degrés & min. D M.
1781. Mars 20	93.	7. 35. 14	113. 48. 35	23. 19. 45 A	0. 8
24 M. Méchain.	94.	12. 40. 43	190. 10. 46 190. 9. 38	42. 18. 43 B 42. 18. 50	0. 2½
24 M. Méchain.	95.	10. 32. 12	158. 3. 5 158. 6. 23	12. 50. 21 B 12. 49. 50	
24 M. Méchain.	96.	10. 35. 5	158. 46. 20 158. 48. 0	12. 58. 9 B 12. 57. 33	
24	97.	11. 1. 15	165. 18. 40	56. 13. 30 A	0. 2

265 1784.

N.os des Nébul.	Détails des Nébuleuses & des amas d'Étoiles. *Les positions sont rapportées ci-contre.*
	très-bien avec une lunette d'un pied. Elle ne contient aucune étoile; le centre en eſt clair & brillant, environné de nébuloſité & reſſemble au noyau d'une groſſe Comète: ſa lumière, ſa grandeur, approchent beaucoup de la nébuleuſe qui eſt dans la ceinture d'Hercule. Voyez *n.° 13* de ce Catalogue: ſa poſition a été déterminée, en la comparant directement à l'étoile *e* d'Hercule, quatrième grandeur: la nébuleuſe & l'étoile ſur le même parallèle.
93.	Amas de petites étoiles, ſans nébuloſité, entre le grand Chien & la proue du Navire.
94.	Nébuleuſe ſans étoile, au-deſſus du cœur de Charles, ſur le parallèle de l'étoile *n.° 8*, ſixième grandeur des Lévriers, ſuivant Flamſteed: le centre en eſt brillant & la nébuloſité peu diffuſe. Elle reſſemble à la nébuleuſe qui eſt au deſſous du Lièvre, *n.° 79*; mais celle-ci eſt plus belle & plus brillante: M. Méchain en fit la découverte le 22 Mars 1781.
95.	Nébuleuſe ſans étoile, dans le Lion, au-deſſus de l'étoile *l*: ſa lumière eſt très-foible.
96.	Nébuleuſe ſans étoile, dans le Lion, près de la précédente; celle-ci moins apparente, toutes deux ſur le parallèle de *Régulus*; elles reſſemblent aux deux Nébuleuſes de la Vierge, *n.os 84 & 86*. M. Méchain les vit toutes deux le 20 Mars 1781.
97.	Nébuleuſe dans la grande Ourſe, près de *β*: elle eſt difficile à voir, rapporte M. Méchain, ſur-tout quand on éclaire les fils du micromètre: ſa lumière eſt foible, ſans étoile. M. Méchain la vit pour la première fois le 16 Février 1781, & la poſition eſt rapportée d'après lui. Près de cette nébuleuſe il en vit une autre, qui n'a pas encore été déterminée, ainſi qu'une troiſième qui eſt auprès de *γ* de la grande Ourſe.

2

A photostat of pages from Messier's personal copy of the "Connaissance des Temps" for 1784, showing additions in his handwriting. In the lower right, he has added the position for a galaxy (NGC 3992) near Gamma Ursae Majoris. The writing in the lower left records Méchain's discovery on May 11, 1781, of NGC 4594, sometimes called M104. Messier also crossed off the "A" erroneously designating a southern declination for M97. Courtesy Mme. G. Camille Flammarion.

personal notations are of interest. The printed description of M97 (the Owl nebula) reads in part, "near by this nebula is seen another, which has not been measured, and also a third which is near Gamma of Ursa Major"; following this, Messier has written in the position of NGC 3992. Oddly, positions have been added by hand for both M102 and M103, in spite of Méchain's claim that 101 and 102 were identical. (There is no obvious object at this erroneous position for M102.) Some of the notations were made in the spring of 1790, proving that this copy was still in use many years after the error was known.

The nature of the added remarks in Messier's copy indicates that they were in part additions made soon after the original publication, and were in part intended for a revision to be published after 1790. Political turmoil in France and inflation prevented publication during that time. It seems odd, however, that a revised list had not been published during the six years (1785-1790) immediately following republication of the list in the 1787 almanac, when Méchain himself served as editor.

The French revolution brought trying times to Messier, as well as to his colleagues, many of whom were scattered from Paris. Soon after he had become a pensioned academician, the Royal Academy was suppressed. Messier lost his pensions and his salary from the navy. At the same time, the navy stopped paying the rent of his observatory at the Hôtel de Cluny. Fortunately, he had some savings, but his means were very limited. Messier was forced to go to Lalande to get oil for the lamp he used during his observing. In September of 1793 he discovered another comet, sending his observations to Saron who finished computing the orbit in prison a few days before he was guillotined.

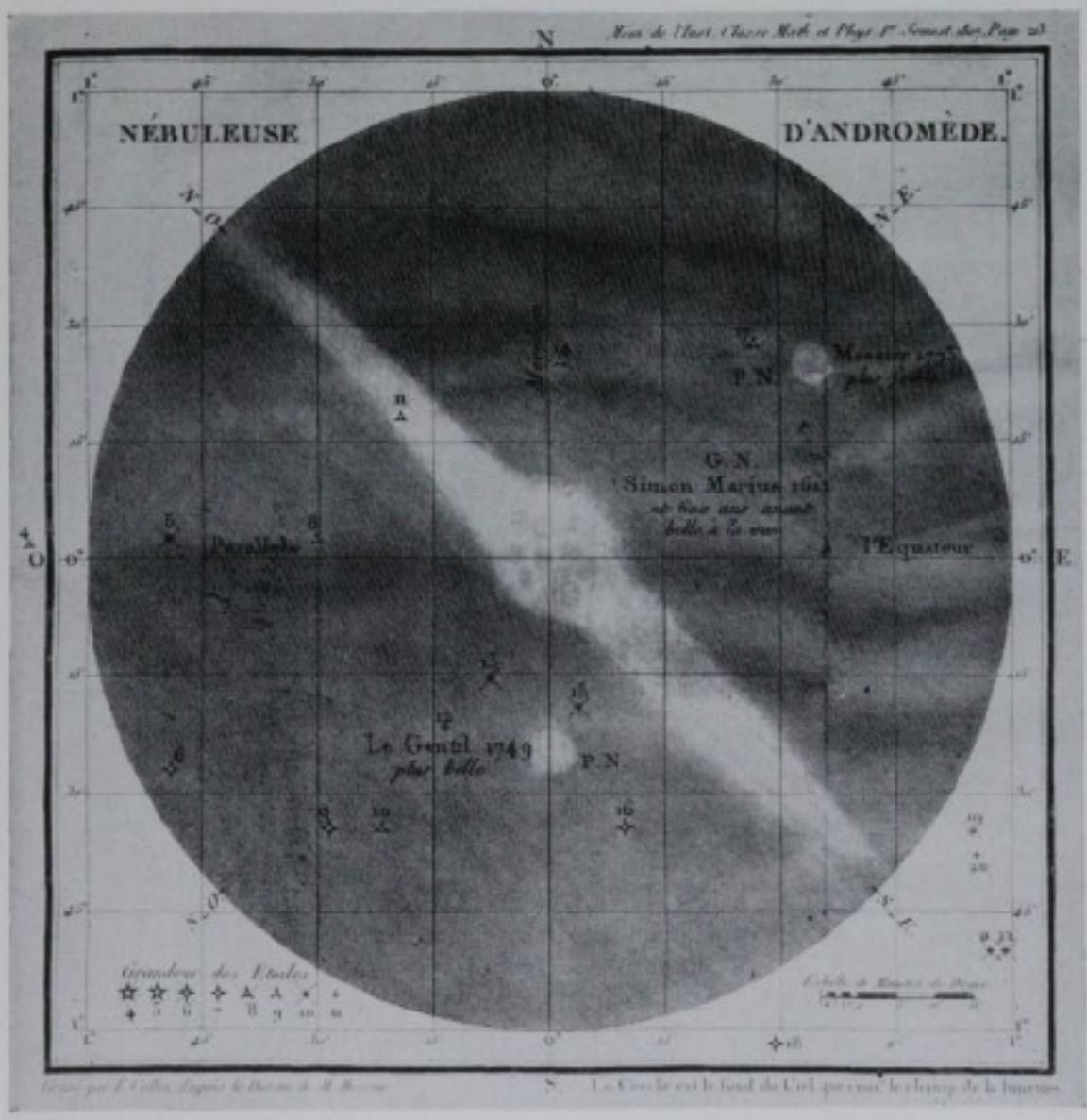
When, in 1791, the National Assembly decided to introduce a general metric system of measurement, Méchain was chosen to survey the southern half of the base line from Dunkerque to Barcelona from which the standard meter was derived. For seven years he worked in Spain and the Pyrenees. Although he was away from Paris during the bloodshed there, his family remained in that city and he lost all savings and his estate.

Fortunes improved for both astronomers, however. For a few years before his death in 1805, Méchain was director of the Paris Observatory. Both Méchain and Messier became members of the new Academy of Sciences, and the Bureau of Longitudes. From Napoleon, Messier received the cross of the Legion of Honor. He had no children, but during his last 19 years his niece gave him assiduous care. After a stroke his strength diminished, and he spent the last two years at home. He lived to the age of 86, dying April 12, 1817.

Looking back on his interest in nebulae, Messier wrote in the *Connaissance des Temps* for 1801: "What caused me to undertake the catalogue was the nebula I discovered above the southern horn of Taurus on September 12, 1758, while observing the comet of that year. . . . This nebula had such a resemblance to a comet, in its form and brightness, that I endeavored to find others, so that astronomers would not confuse these same nebulae with comets just beginning to shine. I observed further with the proper refractors for the search of comets, and this is the purpose I had in forming the catalogue. After me, the celebrated Herschel published a catalogue of 2,000 which he has observed. This unveiling of the sky, made with instruments of great aperture, does not help in a perusal of the sky for faint comets. Thus my object is different from his, as I only need nebulae visible in a telescope of two feet [length]. Since the publication of my catalogue I have observed still others; I will publish them in the future, according to the order of right ascension, for the purpose of making them more easy to recognize, and for those searching for comets to remain in less uncertainty."

What were the other, newly observed objects? A handwritten list of the catalogue objects in order of right ascension is included in his personal copy of the catalogue, but with no additions. Undoubtedly the objects reported by Méchain were among the new ones, although Messier never mentioned these in print. In fact, Messier himself, to my knowledge, never published further information about new nebulae and clusters, with a single exception. One of his last memoirs, in 1807, discussed the Andromeda galaxy and two faint companions. A fine engraving illustrated all three nebulae. Only one of the companions, M32, was included in the original list, although the second (NGC 205) had been found by him as early as August 10, 1773.

In 1921, when Camille Flammarion worked intensively on the Messier catalogue, he found an addition in Messier's personal working copy, and designated this nebula in Virgo (NGC 4594) as M104. A few years ago, after Dr. Helen Sawyer Hogg brought to light Méchain's letter to the *Berliner Astronomisches Jahrbuch*, she identified four of

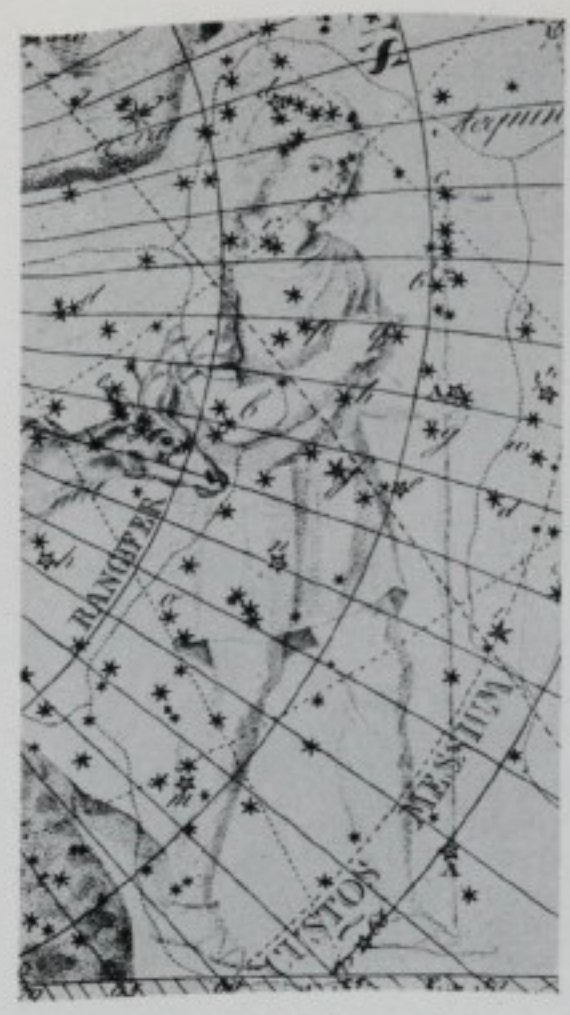


Messier's drawing of the Andromeda galaxy, M31, and its companions, published in the memoirs of the French National Institute (1807). Simon Marius viewed this galaxy telescopically in 1611, but the Arabs had observed it 600 years earlier. Messier credits M32 to Le Gentil in 1749, and NGC 205 to himself in 1773. The circle represents the field of view of his telescope.

Méchain's new objects. Since one was the same as Flammarion had found, she suggested that the other three should be numbered consecutively to M107.

Although Flammarion found Messier's notation of the position of the nebula near Gamma Ursae Majoris, mentioned earlier in this article, he made no attempt to number it, and because Méchain did not give precise positions, Dr. Hogg omitted identifications of this and the other nebula near Beta Ursae Majoris. From my study of this region, the nebula near Beta is unambiguously NGC 3556, while an examination of the critical limiting magnitude of the catalogue indicates that the one near Gamma must be NGC 3992, a fact confirmed by the position Messier added to his personal copy. Thus, if the objects from M104 to M107 are included, it seems logical to me to number NGC 3556 and NGC 3992 as M108 and M109 respectively, especially since they are mentioned in the original catalogue.

But we have only circumstantial evidence that Messier ever observed any of these, and none of them received his sanction in print, nor did Bode include these new positions with the Messier list when he printed Méchain's letter. Furthermore, we have evidence that Messier knew of other nebulae, and specifically NGC 205 in Andromeda, which never received classification. Finally, contemporary workers, such as the Herschels, never considered as part of the Messier list any objects beyond the final 103 in the *Connaissance des Temps* for 1784 and 1787. Deducting such errors or mysteries as M40, M46, M47, M91, M102 (and possibly M73, four stars without nebulosity in Aquarius), the actual catalogue, in my opinion, includes less than 100



The constellation Messier as pictured in Bode's atlas of 1801.

recognized objects, numbered to 103.

Why did Messier never publish his own revised list? Perhaps his perfectionist nature prevented the release of an incomplete list. More likely, he probably never got around to it. Although his observations and reductions continued, he was not always well and his sight began to fail in later years. In 1802, when Messier was 72, Herschel visited Paris, and wrote in his diary, "A few days ago I saw Mr. Messier at his lodgings. He complained of having suffered much from his accident of falling into an ice cellar. He is still very assiduous in observing, and regretted that he had not interest enough to get the windows mended in a kind of tower where his instruments are; but keeps up his spirits. He appeared to be a very sensible man in conversation. Merit is not always rewarded as it ought to be."

In 1775 Lalande formed a constellation Messier on his new globe. Later it was included in the Paris edition of Flamsteed's atlas, and Bode's *Uranographia,* reproduced in part here. Wrote Lalande, "A 'messier' [keeper of the crops] is one who superintends the guarding of the grain. The constellation which carries this name is between Cepheus, Cassiopeia, and Camelopardalis, that is to say, between the rulers of an agrarian people and an animal destructive to the crops. This name will recall to the memory and recognition of astronomers yet to come, the courage and zeal of our most indefatigable observer, Messier, who, since 1757, seems to be in charge of guarding the sky and discovering the comets."

ACKNOWLEDGMENTS

In addition to the references cited in the text, extensive information on Messier and Mechain is found in Delambre's *Histoire de l'Astronomie au Dix-huitieme Siecle* (Paris, 1827) and Lalande's *Bibliographie Astronomique* (Paris, 1803). Messier's own detailed accounts of his observations appear in the volumes of the *Connaissance des Temps* for 1799, 1800, 1801, 1807, 1809, and 1810.

I wish to thank Dr. Helen Sawyer Hogg and Miss Sally Hogg for several major translations used for this research; Mme. G. Camille Flammarion for photographs of Messier's personal catalogue; and Bernard Roy for the use of the pictures of Messier and his wife.

NEWS NOTES

(Continued from page 286)

Rendus, 233, 305, 1951, and *235,* 503, 1952. In the latter the photographs of Saturn and Theta Orionis are reproduced.

Commenting on this work, in the March, 1953, issue of the *Irish Astronomical Journal,* E. B. Armstrong says, "The little picture of Saturn in Comptes Rendus may thus be the forerunner of many unsuspected astronomical sights, at present beyond the reach of the best telescopes."

MOSAIC MIRRORS

Recently there has been a revival of interest in the possibility of making large reflecting telescopes with composite mirrors. The Finnish astronomer, Y. Väisälä, has discussed this idea in the Spanish magazine *Urania, 34,* 89, 1949. At the Bologna Observatory in Italy a mosaic-type mirror nearly six feet across has been constructed, and is described by G. Horn-d'Arturo in the *Journal* of the British Astronomical Association for January, 1953.

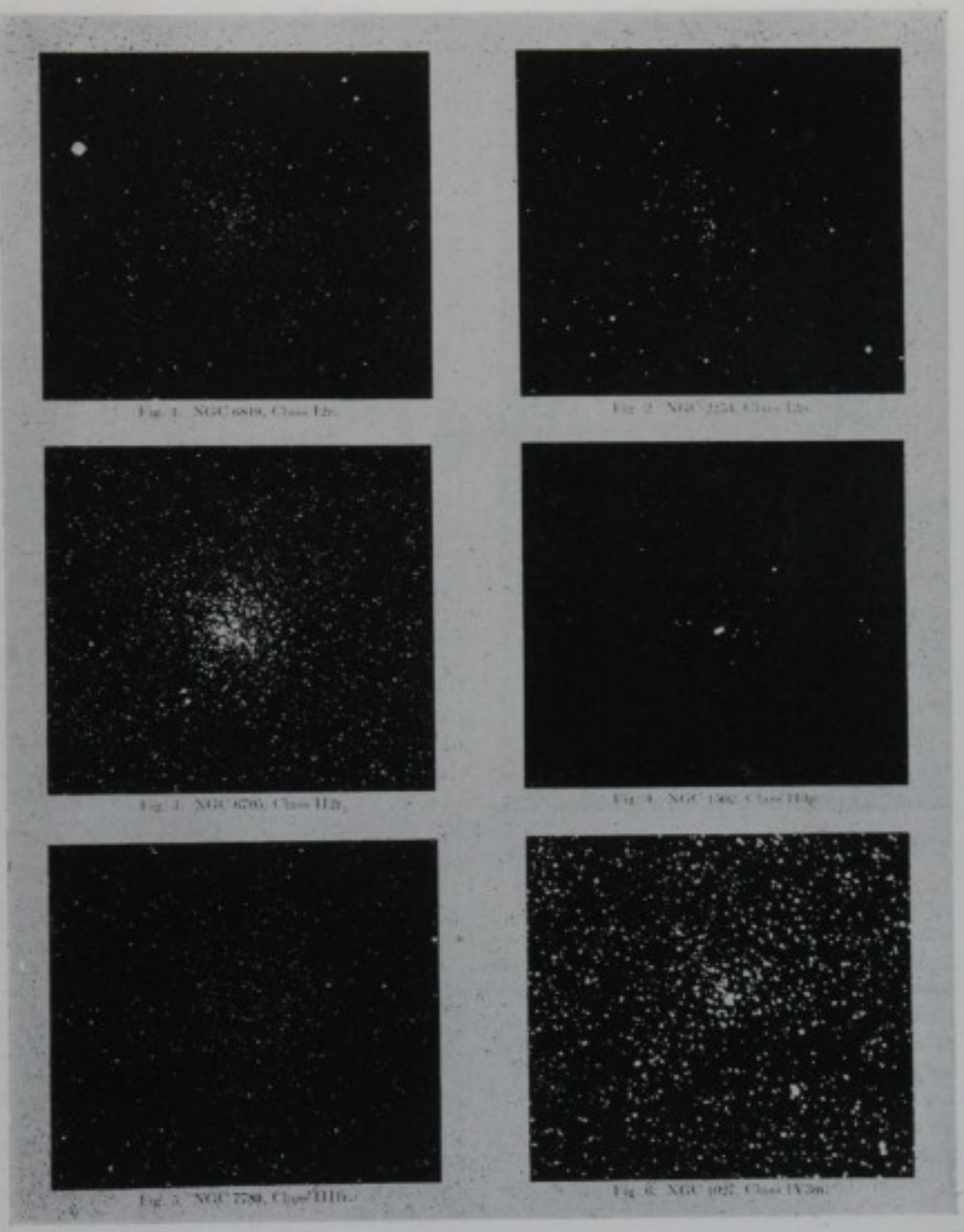
Ordinary mirrors of this size are, of course, almost prohibitively expensive, but mosaic or tessellated mirrors are much cheaper to build. The one at Bologna consists of 61 hexagons, each just under 20 centimeters in diameter and three centimeters thick, and having a radius of curvature of 20.82 meters, or a focal length of 10.41 meters. To minimize spherical aberration, the pieces in each successive zone are slightly raised above the zone next nearer the center; the fifth or outer zone is 7.68 millimeters above the central piece. This mosaic is mounted on a fixed horizontal marble slab, and adjustments of each of the 61 segments are easily made.

Used visually the instrument is inferior to conventional telescopes, but for photographic work atmospheric turbulence and the spread of the photographic image permit more liberal tolerances, so that the Horn-d'Arturo tessellated mirror has proved satisfactory. Since the mirror is mounted in a fixed position, only the zenith can be photographed, by moving a 9-by-24-centimeter plate within the focal plane. As the scale of the photographs is three millimeters to one minute of arc, the long dimension of the field is 1.3 degrees.

Additional information on mosaic mirrors can be found in Dr. Horn-d'Arturo's papers in *Pubblicazioni dell'O[illegible]orio di Bologna, 3,* No. 3, [illegible]; *5,* No. 11, 1950; *5,* No. 17, 1952; and in *Scientific American* for January, 1951, page 60, and for May, 1951, page 76. *El Universo,* publication of the Astronomical Society of Mexico, for October-December, 1952, carries a Spanish translation of material by Dr. Horn-d'Arturo.

METEORITICAL SOCIETY

The 16th meeting of the Meteoritical Society will be held in the Randall Physics Laboratory of the University of Pennsylvania on its Philadelphia campus, September 2-4, 1953. The general sessions will be open to the public, and members of the American Meteor Society are particularly invited to attend.



The six open clusters shown here illustrate one of R. J. Trumpler's methods of typing these objects. From the Lick Observatory "Bulletin," 1930.

Galactic Star Clusters

By Otto Struve, *Leuschner Observatory*
University of California

WE DISTINGUISH, in our galaxy, four types of star groupings: the open or galactic star clusters, the stellar associations, the star-clouds of the Milky Way, and the globular clusters. The first three are concentrated toward the plane of the system, and they therefore belong to the rapidly rotating spiral structure of our galaxy. The globular clusters show no preference for the plane of the Milky Way; they are distributed with spherical symmetry around the center of the galaxy, and they appear to belong to a slowly rotating system of stars that shares the galactic center and orientation of axis with the rapidly rotating spiral arms.

Open clusters will be our chief concern in this month's discussion. Next month, in a sequel to this article, other types and some evolutionary problems will be considered, for star groupings are of fundamental importance in the theory of the origin and evolution of the galaxy.

The number of open clusters is probably very great, for only the nearest can be distinguished from the background of faint stars in the Milky Way. Approximately 500 are now known, and many of these have been quite adequately investigated already.

They differ in structure, size, and composition. Hence, R. J. Trumpler has prepared two distinct schemes of classification. In one nothing more is needed than a single photograph of each cluster. The clusters are divided into four groups according to the degree of concentration of stars toward their centers. Class I represents a cluster with a strong degree of concentration; in class II the concentration is moderate; in III it is weak. Class IV represents accidental groupings of stars. Each class is subdivided in three subgroups: *p* indicates a "poor" cluster, with a membership of not more than 50 stars; *m* is for from 50 to 100 stars; and *r* is a rich cluster, with more than 100 members.

Trumpler also distinguishes among clusters in which all or most stars are of nearly the same brightness (designated by a 1); those whose stars are fairly uniformly distributed over a large range in apparent magnitude (2); and clusters having a few very bright stars and a large number of faint ones (3).

On this scheme, the Pleiades would be designated as type II 3r; the Coma cluster would be II 3p, and Praesepe would be I 2r.

This system of classification has given excellent results. It enabled Trumpler to compare many clusters, at different distances, and subjected to different amounts of interstellar absorption. It is reasonable to believe that two clusters having identical concentrations, numbers of stars, and star distributions resemble one another in size. Hence, it became possible to estimate the relative distances of the clusters from the sun by measuring their apparent diameters. A ratio of 10 in apparent diameter must correspond to a ratio of 10 in distance, provided the cluster classes are the same. In such a case, the apparent brightnesses of comparable stars in the two clusters — one 10 times as distant as the other — should be in the ratio of 10×10, and all the stars in the more distant cluster should be 100 times or five magnitudes fainter than corresponding stars in the nearer one.

It was one of the great triumphs of astronomy, some 20 years ago, when Trumpler found that this prediction is not fulfilled. The difference in the apparent magnitudes is considerably greater than five, perhaps more nearly of the order of seven magnitudes for average clusters. The extra two magnitudes result from the greater dimming of the more distant clusters by interstellar matter — the classification of clusters had led to this significant discovery.

In recent years, Miss K. A. Barkhatova, in the Soviet Union, has analyzed Trumpler's method and has found — as should have been expected — that the classification is itself slightly affected by

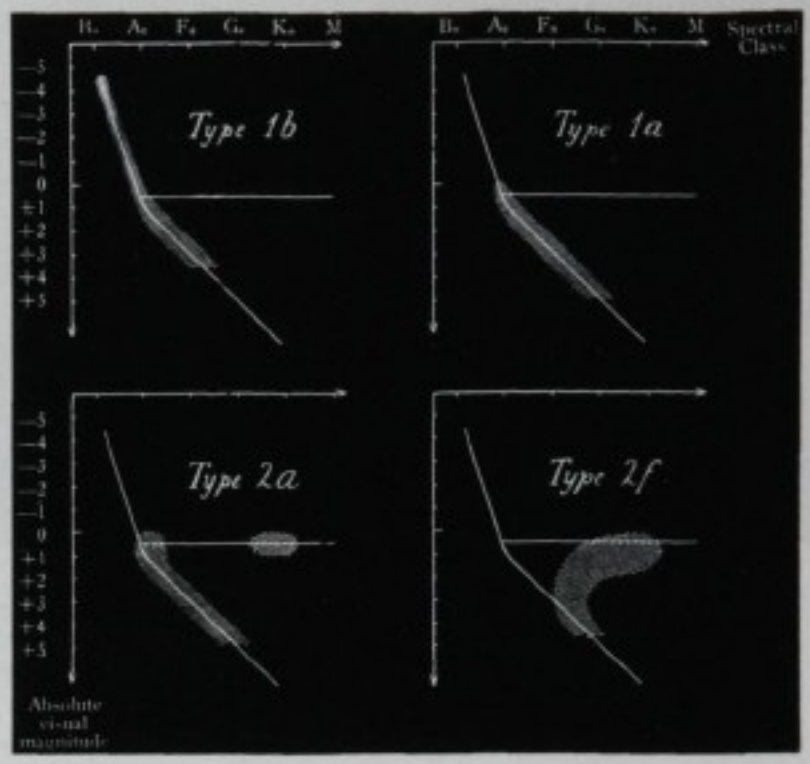
the distance of the cluster. We may not be able to see all the fainter stars of the more distant systems, and our impression of the degree of concentration may to some extent be related to the distance. But these are relatively minor effects.

For those not very numerous open clusters for which either the spectral types or the colors of the individual stars have been determined, Trumpler had earlier introduced a classification based upon rough color-magnitude diagrams. The diagram from Trumpler's original paper (1925) shows the characteristics of four of the several different classes that may be assigned. The small letters are intended to remind us of spectral types (even though only colors are available) of the *brightest* stars in each cluster. The numbers *1*, *2*, and *3* stand, respectively, for clusters with all stars on the main sequence, with most stars on the main sequence and a few in the giant branch, and with most of the brighter stars among the giants while the fainter stars are on the main sequence.

According to this system, the Pleiades and the Double Cluster (see the back cover) would be *1b*, while Praesepe would be *2a*. Trumpler has given a table which shows the distribution of 100 open clusters by this system.

We see from the table that type *1b* (Pleiades) is the most frequent. Also, there is a tendency for the maximum frequencies to run diagonally across the table, from the upper left to the middle right. This is noteworthy: When a cluster has its main sequence all the way to the hottest (*O* or *B*) stars, it rarely contains giants. The latter become more numerous when the cluster has an abbreviated main sequence that extends only to the late *B* and *A* stars.

The Pleiades cluster is classified as II 3r in one Trumpler system and 1b in the other. Ordinarily, the nebulosity around some of the stars is not seen visually, but it is easily photographed. Harvard Observatory photograph.



In one of the Trumpler systems of sorting star clusters, plots of absolute magnitude against spectral type for the stars in each cluster are used for classification. Four of the possible types of clusters are shown here. From "Publications," Astronomical Society of the Pacific, 1925.

NUMBERS OF OPEN CLUSTERS OF DIFFERENT CLASSES

Type	*o*	*b*	*b-a*	*a*	*a-f*	*f*	*Sum*
1	7	24	5	3			39
1-2	3	15	19	3			31
2		1	5	18	1	1	26
2-3				3			3
3				1			1
Sum	10	40	20	28	1	1	100

These features are related to the manner of evolution of a cluster, an idea first proposed by G. P. Kuiper. He compared several Hertzsprung-Russell diagrams he had collected from Trumpler's observations with B. Stroemgren's early theoretical diagrams for groups of stars differing in the abundance of hydrogen. The comparison suggested to him that the ages of clusters are not all the same, and that the more luminous main-sequence stars of the older clusters had disappeared or had been converted into giants.

Stroemgren's computations were made before we knew the source of stellar energy, and his diagrams have been modified by later investigations made by him and by many other theoreticians. But the main idea remains still the same: The youngest clusters are probably those of the *1o* type, and the oldest are probably of the *2a* or *2f* types.

Why are there no older types? Such, for example, as might resemble in their H-R diagrams the globular clusters? The latter, on Trumpler's second scheme, could be described as *3g*, provided we make the necessary modification of using the letter type to describe the spectrum (or color) of the brightest *main-sequence* stars in the cluster.

The answer must be that there are no very old open clusters. Long before they can evolve to the stage of a globular cluster (which may have an age of the order of five billion years), they become disrupted by the perturbations caused by the gravitational field of the Milky Way, a subject that we shall discuss further next month.

In 1952, B. E. Markaryan published an atlas of 32 photographs of approximately two dozen open clusters. Made with an 8-12-inch Schmidt telescope at the Burakan Observatory, they form the best collection of such pictures that we now have. The clusters are arranged in three groups, O, B, and A, depending upon the spectra of the brightest stars. He proposes a three-way division of the O group, into clusters with nuclear condensations, with star chains, and with gaseous nebulae. There is as yet no detailed subdivision of the B and A classes, but the principal features of the latter are a marked increase in the total numbers of stars, and the absence of nebulosity, star chains, and multiple systems of the Trapezium kind. There is no indication, at present, to what extent this new classification will supplant Trumpler's system.

It should be noted that some open clusters are embedded in vast volumes of space containing some supergiant stars. For example, the Double Cluster in Perseus, also known as h and Chi Persei, has an outer grouping of *B* and *A* supergiants and some red supergiants that surround both open clusters and form a tenuous stellar "halo" around them. These stars were discovered by W. Bidelman, and they were described by V. A. Ambarzumian as a typical stellar association. "Stellar Associations" were discussed in more detail by the writer in *Sky and Telescope*, July, 1949. W. W. Morgan and his coworkers at Yerkes Observatory have used the words "aggregates of stars" to designate these very tenuous groupings.

Once the color-apparent-magnitude

The Coma Berenices cluster is classified by Trumpler as type II 3p in one system, type 2a in the other. Its distance is about 250 light-years. This Harvard Observatory photograph shows north at the left.

diagram of an open cluster has been constructed, we can match its main sequence with that of a conventional H-R diagram. The ordinates thus give $m - M$ (apparent minus absolute magnitude), or the distance modulus. If the interstellar absorption is known, we obtain from the modulus the distance of the cluster. For the clusters investigated to date the distances range between 50 and 5,000 parsecs, and the diameters range between 1.5 and 20 parsecs, with a maximum frequency of the order of 3.5 parsecs. A parsec is equal to 3¼ light-years.

Of special interest are the resulting star densities, or number of stars per cubic parsec. The accompanying table gives a few of the values listed in W. Becker's *Sterne und Sternsysteme*. The average density of stars in the spiral arm in which the sun is located is 0.07 per cubic parsec. Even in the Hyades the stars are more densely packed than they are in the average spiral arm of the galaxy.

However, entirely different star densities are obtained when we consider those few open clusters that have been discovered not because they form a dense grouping of stars but because their individual motions indicate their physical connection. Among these moving clusters the one of Orion takes on a special significance, with a star density of 0.0004 per cubic parsec. This corresponds to only a single star every 2,500 cubic parsecs. Hence, the members of this group are scattered through the spiral arm and are mixed with the latter, to such an extent that they no longer form a gravitationally compact arrangement.

STAR DENSITIES OF TYPICAL OPEN CLUSTERS

Cluster	*Part of cluster*	*Stars per cubic parsec*
NGC 6705 (M11)	center	83
NGC 6705 (M11)	½ radius	10
NGC 2099 (M37)	center	18
NGC 1960 (M36)	center	12
Pleiades	center	2.8
Praesepe	mean	1.5
h-χ Persei	mean	1.4
Hyades	mean	0.25
Ursa Major	center	0.36

A somewhat similar star density, of the order of 0.0001 per cubic parsec, is obtained for the 126 members of the moving cluster centered in Ursa Major. Comparing this with the table, we see that the star density at the center of this group is nearly 4,000 times greater than the density of the entire moving cluster.

An even smaller star density is obtained for the O and T associations discussed by Ambarzumian. A typical association of the type of NGC 6231 may have 40 members spread over a volume with a radius of 100 parsecs. If we divide 40 by the number of cubic parsecs within this volume, we reach a star density of about one in 100,000 cubic parsecs.

The significance of these densities, and the extremely high densities of the globular clusters, will be considered next month. Meanwhile, the reader may wish to review the discussion by Bart J. Bok, "Dynamics and Evolution of Star Clusters," that appeared in the July and August, 1951, numbers of *Sky and Telescope*.

AMATEUR ASTRONOMERS

(Continued from page 287)

first nine months over 700 visitors registered during Friday evenings when the observatory was open to the public.

Some time later, needed improvements were provided from the college budget, with members of the Sacramento Valley Astronomical Society contributing their time and talents. This society has from its inception been affiliated with Sacramento Junior College. In May, 1939, the society's board of directors decided that the rapid growth of community interest justified further investment in the observatory. Three expert optical men, Dr. Robert E. Smith, Dr. R. B. Giffin, and Carl E. Wells, assisted from time to time by other members, ground and polished a 12½-inch mirror of excellent quality, which was finally mounted in a steel lattice-work tube fabricated at the Southern Pacific Railroad shops. It took about two years to complete this fine Newtonian telescope. It has electrically driven slow-motion mechanism, and is equipped with a camera for stellar photography and special lenses for solar photography.

During the war years, the observatory was not in operation, but in 1946 much progress was made reviving astronomical interest in the community, and further improvements were added to the observatory equipment. In 1947, Leon E. Salanave was appointed astronomy instructor at the college and director of the observatory. Under his leadership, general interest in the observatory was brought to its highest peak. Thousands of visitors came each year from all over northern California. Professional astronomers from the University of California, the Lick, Griffith, and Mount Wilson and Palomar observatories, came to give public lectures. Since Mr. Salanave's resignation to join the staff of the Morrison Planetarium in July, 1952, the college observatory has been conducted by the society, pending appointment of an astronomy instructor on the faculty.

A regular solar observing program is currently being carried on by the writer. The special solar photographic equipment was designed by Professor Salanave and constructed with the collaboration of Julian Felkey, Charles A. Fogus, and myself.

Throughout the summers, and at other times, the observatory is opened to the public. The crowds last year overtaxed the facilities, and new alterations to the building will now permit from three to five times more visitors to view the stars.

All the activities and interests of the Sacramento society focus on the observatory. For the pleasures and profits it affords, we thank the enterprising Henry Hughes—who had neither money nor experience to build an observatory, but who found a way.

VICTOR W. KILLICK
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BOOKS AND THE SKY

ASTROPHYSICS

The Atmospheres of the Sun and Stars

Lawrence H. Aller. Ronald Press Co., New York, 1953. 412 pages. $12.00.

THE SUBTITLE should always be used for this book, for many of the most important parts of astrophysics, specifically "nuclear transformations and stellar interiors, variable stars, and the interstellar medium," have been set aside for treatment in a later volume. Evidently this was done in order that the present work might have room for enough fundamental physics to form a nearly self-contained introduction to astrophysics. The book grew out of the material given by the author in first-year graduate courses, and can be used either as a text for such a course or for study by anyone who wants or needs to come to grips with the central problems of astrophysics in its present state.

The need for such a work has been obvious for some years; there has been no other modern text in English which is at once rigorous and comprehensive enough to put the student in a position to read intelligently the current astrophysical literature. The interesting question is how well the author has met this need. I feel first of all that Dr. Aller made a sound start by integrating so much basic physics into the texture of the treatment. In approaching the question of the structure of the observable surface layers of a star, for example, one is almost always faced immediately with the problem of analyzing radiation that has traversed a long path through matter of varying density. Little progress can be made until one understands the general methods of dealing with the transfer of radiation. Such terms as **optical depth** and **specific intensity** must be defined and made familiar, but the aspiring student who turns to physics and looks into the standard works dealing with radiation and matter will have a long search; and then he is unlikely to find a discussion employing the units and nomenclature that have come into general astrophysical use. This is at least partly because physicists can generally arrange their experiments in such a way that only the simpler transfer problems need to be considered. It is true, of course, that these topics are now elegantly treated in recent works by Chandrasekhar and by Kourganoff, but most students will find it best to read Aller first and let him provide the introduction to the more specialized treatises.

On the other hand it is not so certain that it was worth while to include a systematic review of the more familiar topics of atomic and molecular spectra at the expense of more purely astrophysical material. It must be admitted, however, that it is convenient to have such a concise compilation of the formulae for the structure and intensities of lines and bands.

The second half of the volume goes step by step through the many problems involved in analyzing the atmospheres of the sun and other stars on the basis of their observed spectra. Neither theory nor observation is slighted, and the presentation is beautifully clear. The teaching experience of the author is evident here, but the treatment also gains strength from his own fundamental research in many parts of this field — particularly on line intensities and curves of growth.

Astrophysics is still a rapidly changing subject, and it was inevitable that a few of the sections should have become partly obsolete even while the book was in press. Thus the concept of stellar population groups, discussed in the first chapter, is in a very fluid state just now. Also the statement on page 14 that the color-magnitude plot for clusters such as the Pleiades and Hyades "gives a well-defined curve with very little scatter" should be modified in view of the recent accurate data obtained photoelectrically by Johnson, Hiltner, and Harris. Their independent measurements agree in showing that the main sequence possesses considerable real dispersion. These are only small points, and do not obscure the thoroughness and fairness with which Aller has summarized and appraised the significant recent contributions. The bibliographies at the ends of the chapters are an outstanding feature of the book.

One pair of misprints could cause confusion if not corrected in users' copies. The legends have been interchanged for Figs. 7 and 8 on pages 93 and 94, which are Russell's diagrams of molecular abundances. It is Fig. 8 which actually refers to giant stars. On the whole, though, the publishers should be congratulated on the clarity of the typography and the excellence of the illustrations.

P. C. KEENAN
Perkins Observatory

THE SCIENTIFIC ADVENTURE

Herbert Dingle. Philosophical Library, New York, 1953. 372 pages. $6.00.

SOME PHILOSOPHERS have argued that we can never determine the magnitudes of physical quantities with certainty, and therefore the nature of the physical world must remain forever unknown. The characteristic reaction of the scientist to this is the cliché that "philosophy is the systematic misuse of a terminology especially invented for the purpose," and he blithely keeps on measuring, classifying, correlating and theorizing, and thereby learns more and more about this thing supposedly forever beyond his ken.

Therefore it is refreshing and instructive to read Professor Dingle's collection of essays on both the history and philosophy of science. The author, who is president of the Royal Astronomical Society, writes in terms that an astronomer can understand; his philosophical arguments are highlighted by numerous examples from astronomy and physics. Although the book is divided into two parts, historical and philosophical, and although a scientist will find the philosophical part somewhat heavier going than the historical, the division is not a fundamental one. The author's philosophy permeates his interpretation of science, and vice versa. Most of the essays have been published separately elsewhere and can be read with profit and interest in any order, the unity of the book being found in the viewpoint of the author.

Dingle is not that type of historian who "goes down deeper, stays down longer, and comes up muddier"; rather, he admits that his knowledge of historical facts is entirely secondhand. His contributions are in the **interpretations** of the facts, and he has taken considerable pains to ensure that his interpretations are accurately presented. His historical essays are "Some Reflections on the History of Science," "Astronomy in the Sixteenth and Seventeenth Centuries," "Nicolaus Copernicus (1473-1543)," "The Quest for Accuracy in Astronomy: The Message of Four Centenaries," "Galileo Galilei (1564-1642)," "Thomas Wright's Astronomical Heritage," "Physics in the Eighteenth Century," "Modern Theories of the Origin of the Universe."

The breadth and sparkle of **The Scientific Adventure** can best be indicated by a few quotations from it.

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Jupiter, that the Moon had been a few miles farther away, and that the discovery of white dwarf stars had been postponed for a few years. Then there is no doubt that Einstein's theory would have remained a curiosity, and science would still have held to Newton's law as proven truth."

"Kepler is roused to the same rhapsody by his theory of the five regular solids as by the laws which now bear his name; the first is forgotten, the second lie at the basis of dynamical astronomy. Doppler maintains that the movement of a star in the line of sight should change its colour. He is wrong, but the fact which he imperfectly apprehended was rescued from the rubbish and has led to what may be the most significant discovery yet made about the physical universe. Balmer, no scientist, but a numerical mystic, produced innumerable mathematical fatuities, and among them the regularity exhibited by the wave-lengths of the hydrogen spectrum lines. The last was taken and the others left, and it has become the starting point of the modern theory of the atom. Over the terrain of rocks and quicksands science walks as sure-footed as a mule—and as sapient."

"Until the present generation, and perhaps even now, Newton's law of gravitation stood at the high-water mark of exactness in science, and it is not often realized that it was extracted from data which the modern observer would reject out of hand." "Newton's supreme achievement passed the tests of nearly a quarter of a millenium, and then, by the tiniest shake of the head, Nature interposed her veto, and the whole fabric was shattered."

Dingle makes the following pungent comments on some modern cosmologies and cosmologists:

"The matter is supposed just to appear. Jordan, it is true, provides the raw energy for it, but this also is purely hypothetical, and how gravitational energy can change into material atoms is beyond conjecture. Such a magic transformation in the observable world of science has not been admitted since the alchemists proposed to change lead into gold by means of the philosopher's stone. The new hypothesis is, in fact, precisely similar to that, except that the philosopher's stone has been forgotten and in Hoyle's version, the lead as well." "If I may venture to use a libellous metaphor, I would say that Jordan offends against the proprieties outrageously, but the law cannot touch him because of a loophole in it that escaped the notice of the legislators. Hoyle, on the other hand, knows that he is breaking the law but does it so surreptitiously that it is impossible to get the evidence on which to convict him." "Our conception of the universe in a hundred years' time is likely to be as different from that of the present day as that is from the ideas of Lockyer. The philosopher or theologian who builds his system on the models of the universe that we now construct is building on a foundation of sand."

The aim of Dingle's scientific philosophy is to organize the whole of experience into a rationally connected system. Unlike most previous philosophies, it does not accept the world of material objects as a necessary starting point, but goes back to the original experiences that led to the conception of that world, and groups these experiences differently. Instead of associating grayness and heaviness with lead and yellowness and lightness with sulphur, it seeks first the relation between grayness and yellowness on the one hand, heaviness and lightness on the other, and only much later does it arrive at an inexpressibly indirect connection between the color and density of any of the pieces of matter which at first glance would seem to be indivisible units. Dingle asserts that scientists have practiced this philosophy, perhaps unconsciously, from the time of Galileo onward, and that it has been the mainspring of the remarkable impetus that post-Galilean science reveals. He further submits that, if his view is correct, **there is no realm of experience which is excluded from scientific treatment.** Therefore he takes strong exception to Eddington's statement that "The cleavage between the scientific and the extra-scientific domain of experience is, I believe, not a cleavage between the concrete and the transcendental but between the metrical and the non-metrical." Darwin's theory of evolution is given as an example of scientific work which, Dingle asserts, has nothing whatever to do with measurement. This is, perhaps, an unfortunate choice of an example because Darwin, to some extent at least, made measurements and, to a much greater extent, classified things. Some scientists today would argue that classification is a form—although sometimes a very indirect form—of measurement; consider, for example, the Henry Draper spectral classification.

Dingle argues that "To ask whether a number is 21 or 22 is like asking whether an animal is a horse or a cow; the answer is absolutely right or wrong. It is not like asking whether a parallax is 0.532 or 0.533 seconds of arc, where . . . every improvement in measurement simply transfers the uncertainty to the next decimal place." He is somewhat more fortunate here in his choice of an example because he might have written "horse or donkey," "lion or tiger," "rabbit or cat"; and there are such animals as mules, ligers (or tigions) and rabbicats.

The last two chapters of the book are on "Science and Ethics" and "Science and Religion" and are well worth reading. In Dingle's philosophy ethical and religious experiences can and should be treated in scientific fashion; he sees no reason for believing that theological statements are beyond rational discussion. Those scientists who have suffered through half-baked discussions of the relation or conflict between science and religion will enjoy especially the final chapter, and will agree with the reviewer that it is "well done."

JOHN B. IRWIN
Goethe Link Observatory

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OUR NEIGHBOUR WORLDS, *V. A. Firsoff*, 1953, *Philosophical Library*, 336 pages. $6.00.

This book on the solar system, and the possibilities of space flight in it, is now available through an American publisher. The book was reviewed by Dr. J. A. Hynek in the June, 1953, issue of *Sky and Telescope*.

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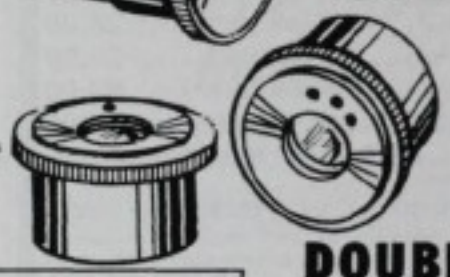

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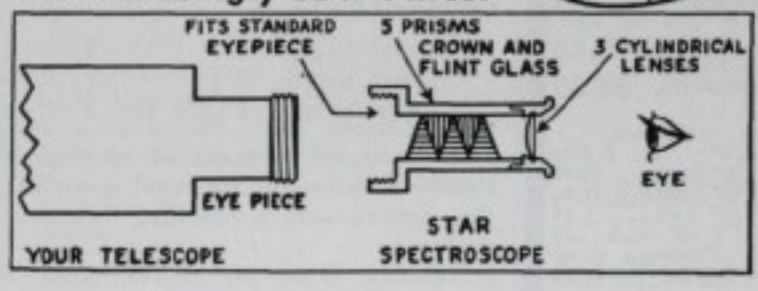

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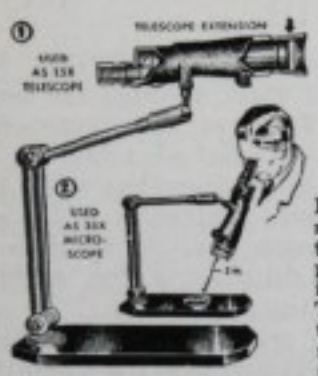

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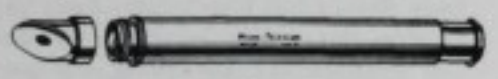

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GLEANINGS FOR ATM's

EDITED BY EARLE B. BROWN

Notes on Basic Optics — III

C. Two Simple Lenses in Series

1. Image Formation. In our previous installments, we discussed the properties of simple lenses. The next step is to examine how two simple lenses in combination will act. The image formation by a pair of lenses can be worked out by applying the principles already outlined to each of the lenses in succession. But regarding the two lenses as a unit leads to certain interesting and useful concepts.

Let us start by considering two positive lenses separated by a distance less than either of their focal lengths. Figs. 9 and 10, which show this situation, may not be easy to follow, but they are highly instructive. The reader is urged to draw these diagrams on a separate sheet of paper, line by line, as he reads through the following discussion.

In Fig. 9, the two lenses I and II are first drawn in, and their focal points, $\mathbf{f}(I)_1$, $\mathbf{f}(I)_2$, $\mathbf{f}(II)_1$, and $\mathbf{f}(II)_2$ are located as usual. For the diagram, the following values were chosen:

Focal length of I: $\mathbf{f}_1 = 6$
Focal length of II: $\mathbf{f}_2 = 5$
Separation of I and II: $\mathbf{t} = 4$

It is desirable to make all of these three numbers different, to avoid symmetry of the picture and a resulting loss of generality.

Starting from an object point **P**(I), which has been placed inside $\mathbf{f}(I)_2$ to make the picture simpler, we construct **P**(I)**A**(I) parallel to the optical axis. Then draw **A**(I)$\mathbf{f}(I)_1$, labeling its intersection with lens II as **B**(I), and extend it leftward; and also, draw **O**(I)**P**(I), and extend it to meet the previous line at **P'**(I). The key to our process is that **P'**(I) is not only the virtual image formed by lens I, but at the same time **P'**(I) is the object **P**(II) for lens II. We construct the final image **P'**(II) by drawing another set of rays: **P**(II)**A**(II), then **A**(II)**P'**(II) through $\mathbf{f}(II)_1$, and finally **P**(II)**P'**(II) through **O**(II). Thus we find that the two lenses together form the final image **P'**(II).

So far this has been a repetition of what we have done before. But now let us continue the actual ray **P**(I)**A**(I)**B**(I) through to the final image by drawing **B**(I)**P'**(II). Then we have an entering ray **P**(I)**A**(I) for the two-lens system and an emerging ray **B**(I)**P'**(II). We draw a vertical plane through the intersection point **S**(II) of their extensions. We see that, for the emerging ray at least, the two-lens system has acted just like a single lens, located at **p**(II) and with a focal length equal to the distance **p**(II)**e**. This distance is the **effective focal length** of the combination.

If we try to prove this by drawing a line through **p**(I) and **p**(II), we find that it does not pass through **P'**(II), so we see that a simple lens at **p**(II) is not the whole answer.

Let us now follow the light through the lenses in the reverse direction, starting with **P'**(II) as the original object. The process is shown in Fig. 10, where the lines drawn for Fig. 9 have been repeated as thin lines. We begin by drawing the ray **P'**(II)**a**(II) according to the usual construction. Then **a**(II)$\mathbf{f}(II)_2$ extended will meet **P'**(I), and we label the intersection of this ray with lens I as **B**(II). We can at once draw the ray **B**(II)**P**(I), since we know that **P**(I) will be the final image for this reverse direction. After extending **P**(I)**B**(II) and **P'**(II)**a**(II) to their intersection **S**(I), we see that in this direction the two-lens combination has acted just like a single lens located at **p**(I) and with a focal length equal to **p**(I)**e'**; this last turns out to be the same as the effective focal length in the other direction.

This explains for us why the ray through the center of the equivalent single lens did not work out when we were following the light through in our first direction. When light comes from the left, the center of the equivalent lens is at **p**(I), when from the right, at **p**(II). We can easily verify this conclusion by drawing the line **P**(I)**p**(I) and then the parallel line **p**(II)**P'**(II).

2. Other properties. Some important results follow from a consideration of the vertical lines through **S**(I)**p**(I) (Fig. 10) and **S**(II)**p**(II) (Fig. 9), which are, of course, projections of planes. These are called the **principal planes** of the two-lens system. Now we have just proved that a two-lens system may be treated as a single lens, located either at **p**(I) or at **p**(II), depending upon which direction we are looking.

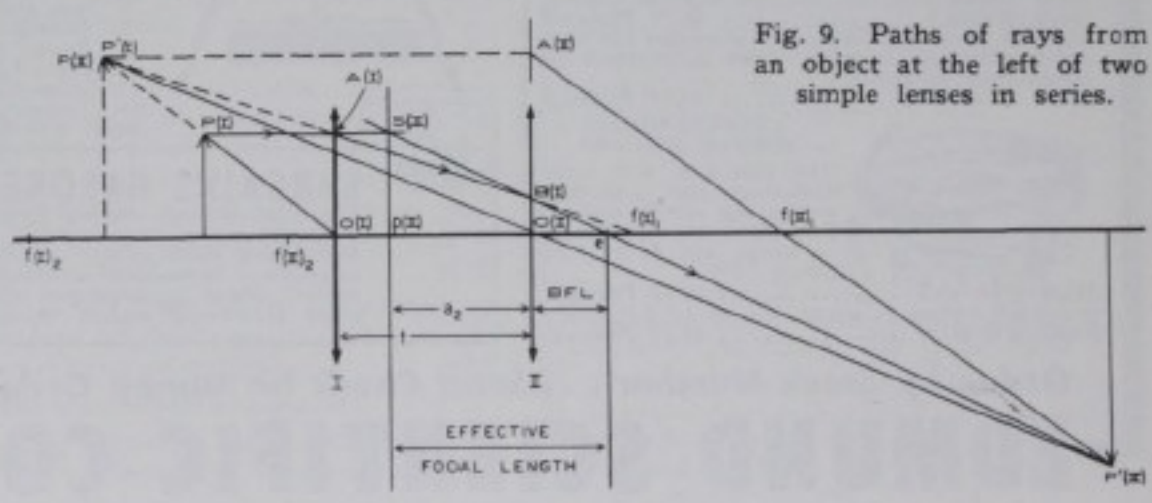

Fig. 9. Paths of rays from an object at the left of two simple lenses in series.

The equations for locating the principal planes of a two-lens system are

$$a_1 = \frac{f_1 t}{f_1 + f_2 - t}, \qquad (3)$$

$$a_2 = \frac{-f_2 t}{f_1 + f_2 - t}, \qquad (4)$$

where the negative signs indicate that the distances are to be measured from the left. Here a_1 is the distance of the first principal plane from lens I, the first principal plane being the one associated with the entering light. The distance of the second principal plane from lens II is a_2, the second principal plane being that associated with the emerging light.

As an example, take the case illustrated in Figs. 9 and 10, for which the formulae give $a_1 = 6\times4/(6+5-4) = 24/7 = 3.43$; and $a_2 = -20/7 = -2.86$. From these values, the distance between the principal planes, $p = t - a_1 + a_2$, becomes $4 - 3.43 - 2.86 = -2.29$. Note that p is negative. This means that the principal planes are crossed: the first principal plane lies to the right of the second. According to the definitions we have been following, this situation should call for the negative sign. Crossed principal planes are characteristic of two positive lenses in combination.

We will see, a little later, that we may also treat a thick lens as a thin lens, finding the principal planes of the thick lens exactly as we did for the two-lens system, by thinking of the thick lens as composed of two separated surfaces. While the material between the two surfaces is not air but glass (or other transparent substance), the calculation is not changed in principle, but only in slight details. In following a ray through a thick lens, first the entering ray is traced to its intersection with the first principal plane; then the emerging ray is traced from the second principal plane, beginning from a point the same height above the axis as obtained at the first principal plane. (See Fig. 11.)

The distance between the principal planes, $p = t - a_1 + a_2$, may be thought of as "empty space" in the optical system. If this space is ignored, then the first-order theory which we have discussed applies to thick components as well as to thin components.

The concept of two thin lenses in series is a highly significant one. We have already seen how we can treat such a pair of lenses as an equivalent single lens. Carrying the idea further, we can deal with any number of lenses as an equivalent single lens (from the standpoint of first-order theory).

But this is not all. Any basic optical instrument may be represented in principle by a pair of optical systems. These, in turn, are equivalent to a pair of thin lenses. Thus we can simulate any optical instrument by two thin lenses.

To do this, let us first find the back focal length (BFL) and the equivalent

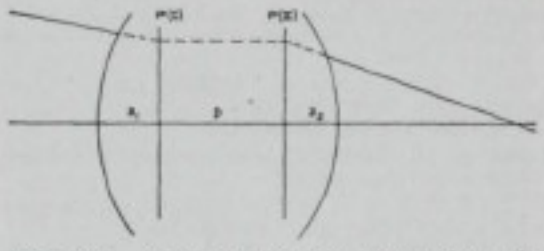

Fig. 11. A schematic representation of a thick lens, showing its refracting surfaces and the locations of its principal planes. The passage of a ray through it is analogous to that through a pair of simple lenses in series.

focal length (EFL) of a pair of thin lenses. The back focal length is defined as the distance $O(II)e$, that is, the distance from the second lens to the first effective focal point. We calculate this from the formula:

$$\mathrm{BFL} = \frac{f_2\,(f_1 - t)}{f_1 + f_2 - t}. \qquad (5)$$

The equivalent focal length, $p(II)e$ or $-p(I)e'$, is obviously BFL $- a_2$, where a_2 is subtracted because it is negative in Fig. 9. And this turns out, after a little algebra, to be:

$$\mathrm{EFL} = \frac{f_1 f_2}{f_1 + f_2 - t}. \qquad (6)$$

These are perfectly general results, which apply not only to Figs. 9 and 10, but to any combination of two thin lenses.

(To be continued)

GLEANINGS is always ready to receive reports and pictures of amateur instruments and devices, and is open for comment, contributions, and questions from its readers.

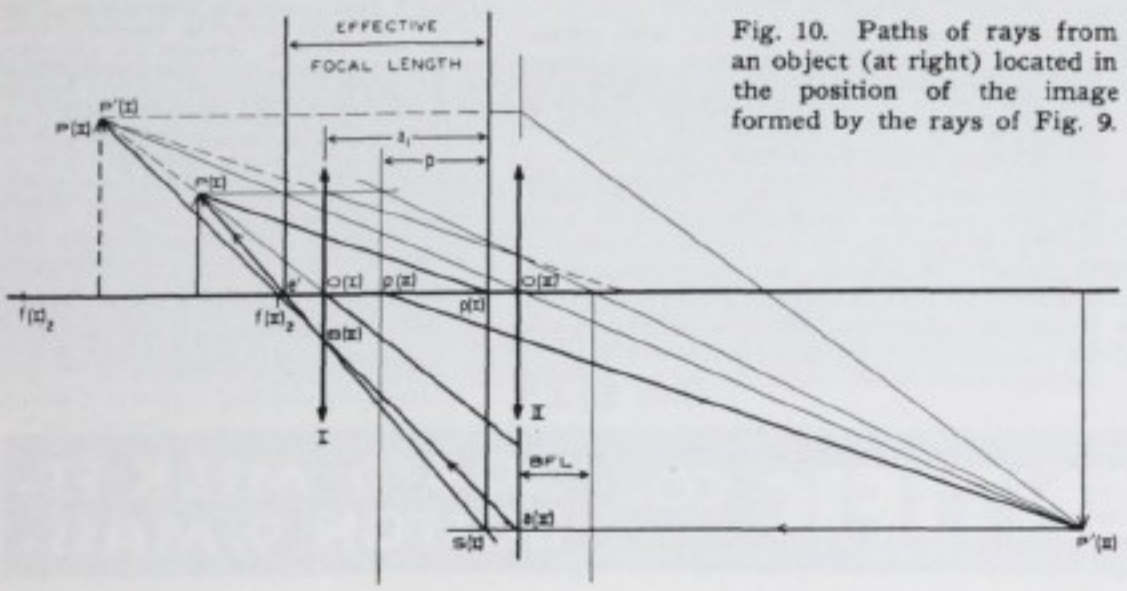

Fig. 10. Paths of rays from an object (at right) located in the position of the image formed by the rays of Fig. 9.

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OBSERVER'S PAGE

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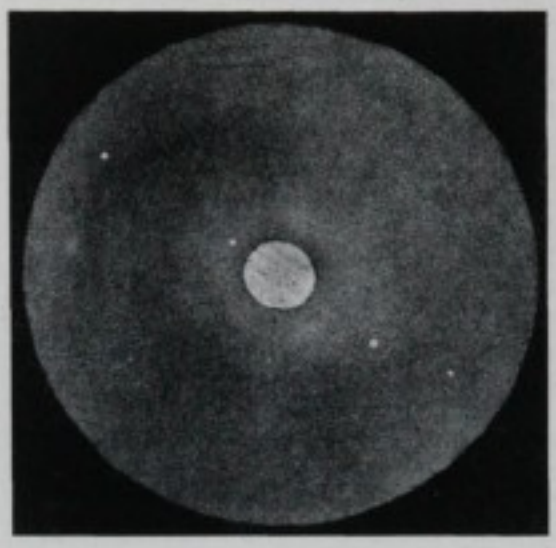
An Introduction to Observing Jupiter — I

WHEN the amateur astronomer turns his telescope upon that monarch of the solar system, giant Jupiter, he will be met by one of the most pleasing and intriguing spectacles that the sun's planetary system has to offer. Even through a telescope of less than three inches aperture the sight of this planet will be immensely rewarding. On getting his first good view of Jupiter through a small telescope, the novice will see what appears to be a rather small disk, whitish or possibly with a slight yellowish tinge. At varying distances from this disk will be seen several starlike points of light, which lie approximately on a line with the equator of the planet. These are the famous satellites of Jupiter.

A closer inspection will show that the planet is not quite round, for the equatorial diameter is longer than the diameter of the disk from pole to pole; this oblateness becomes very apparent to the observer after it is once detected. On this closer inspection, two dusky parallel bands will probably be seen, one on either side of the equator. These are the cloud belts, which we will describe later. In a telescope smaller than three inches, little can be noted of these belts beyond their existence. A slight shading of the disk toward its poles may also be detected. Usually three or four satellites will be seen, the number depending on their positions in relation to the planet, for at times they are eclipsed in its shadow, at times occulted behind the disk, or at times in transit in front of the planet. Predictions of these movements of Jupiter's satellites are published annually in the **American Ephemeris and Nautical Almanac,** which may be purchased from the Superintendent of Documents, Washington 25, D. C.

All these features will be shown by a good-quality small telescope of around 60 power, while the satellites may be detected in good field glasses or binoculars.

When it is at opposition (opposite to the sun in the sky), the planet appears largest and brightest, and it is then that the best views of Jupiter are generally obtained. Oppositions for the next few years will occur in December, 1953; January, 1955; and roughly thereafter at 13-month intervals: February, 1956; March, 1957; April, 1958; May, 1959; June, 1960.



Jupiter and its four large moons, as seen in a small telescope. From Rudaux and de Vaucouleurs, "Astronomie."

Through a 3-inch Telescope

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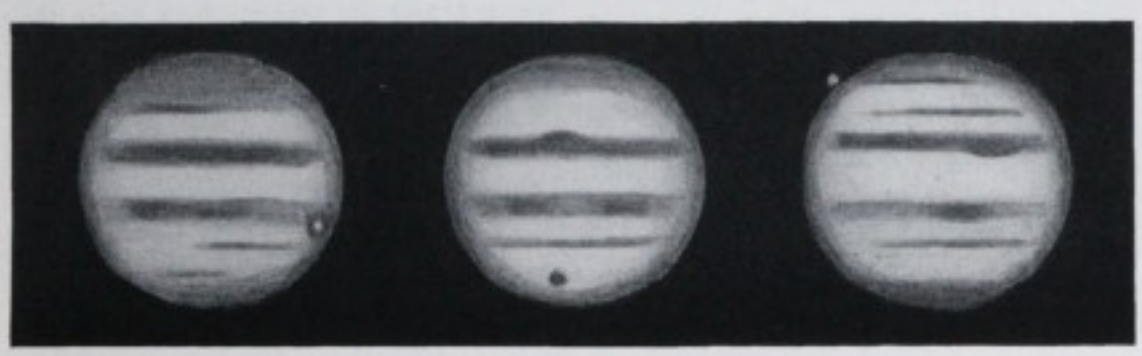
Generally the most useful powers for a 3-inch refractor will be 125x to 175x. The drawings show us what we can expect to see through this instrument when the seeing conditions are good. When the satellites are in transit, they can be seen as bright dots against the darker areas of the disk; when they are in front of the lighter areas they blend into the background and are thus invisible. The shadows cast on the disk by satellites in transit will be very apparent as small black spots traveling over the face of the planet. When the satellites are being occulted, they will readily be seen as they begin to pass behind the disk of Jupiter. When a satellite on the farther side of Jupiter enters into the planet's shadow, the satellite will be seen to fade to invisibility, as it becomes eclipsed.

With our 3-inch glass, we will see more numerous and finer details on the planet itself. In addition to the two dusky bands



Jupiter in a 3-inch telescope, showing moon phenomena and variations in the belts. Left: A satellite begins to transit. Center: A satellite's shadow transit. Right: A satellite disappears in occultation behind Jupiter's disk. In the first two pictures the satellite motion is leftward, in the last to the right. Drawings by D. P. Avigliano.

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encircling the globe that we saw with the smaller telescope, we will see other dusky bands. In general they will run parallel to the equator and lie in the zones between the equatorial belts and the poles. Three to five belts can generally be seen with a 3-inch glass, and on rare occasions when the air is very steady six or more belts can sometimes be glimpsed. The dusky shading of the polar areas will be very apparent, and the edge or limb of the planet will appear appreciably darker than its center. The dark bands themselves become less conspicuous near the limb, because we are actually looking at a globe surrounded by a thick, semitransparent atmosphere. At times the equatorial region (the zone between the two major dark belts) will be seen as the most luminous part of the disk. On occasions of the best seeing we can detect some variations in the larger belts. The colors of the disk and of the satellites will repay attention. Jupiter has a definitely yellowish tinge, while the larger belts are tinted a reddish brown. At times the dusky area may have a bluish tone.

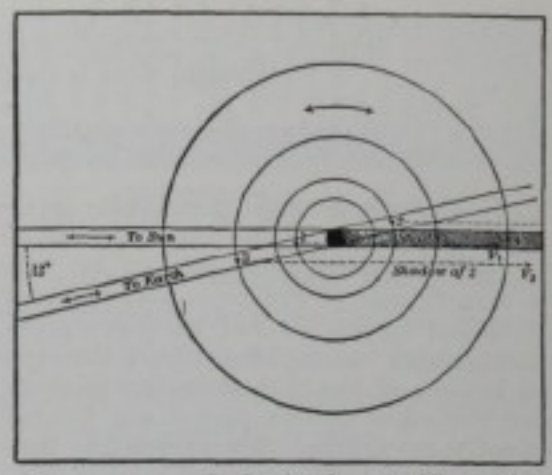
NUMERICAL DATA FOR JUPITER

Mean distance from sun	483.9 million miles
Sidereal period of revolution around sun	11.86 years
Average orbital velocity	8.1 miles per second
Angular diameter (equatorial)	30".8 to 50".0
Equatorial diameter	88,800 miles
Polar diameter	83,000 miles
Volume (earth = 1)	1,318
Mass (earth = 1)	318
Average density (earth = 1)	0.24
Surface gravity (earth = 1)	2.64
Velocity of escape at surface	37 miles per second
Magnitude	−1.1 to −2.5
Reflecting power (albedo)	0.44
Rotation period, System I	$9^h\ 50^m\ 30^s$
Rotation period, System II	$9^h\ 55^m\ 41^s$
Number of satellites	12

(Data chiefly from Russell, Dugan and Stewart, *Astronomy*, Vol. I, 2nd edition)

While watching the planet we will become aware of a change from hour to hour, and soon we realize that we are actually witnessing the rotation of this great world upon its axis. The markings of the globe are shifting in an east-to-west direction, that is, right to left for an observer using an inverting telescope in the Northern Hemisphere. When the planet is observed from night to night, the bands go through variations of their own, appearing and disappearing, and altering in width and darkness.

The continually changing dark belts upon the disk of Jupiter are an ever-interesting spectacle, which together with the behavior of the satellites makes the most fascinating planetary study that the owner of a small telescope can find in our heavens.



Phenomena of Jupiter's satellites (at time of quadrature with the sun): 1, shadow transit; 2, occultation; 3, transit; 4, eclipse. From "Astronomy," by Russell, Dugan and Stewart.

The Satellites

The known satellites are 12 in number, but only the four largest can be seen in amateur telescopes. The identification of these four major satellites can be made by consulting the configuration diagrams in the **American Ephemeris** or those reprinted in **Sky and Telescope.** After gaining experience, the observer may recognize these satellites by their individual appearances. Their characteristics are listed in the table below.

A satellite when in transit is usually visible only shortly after entering or shortly before leaving Jupiter's disk; as we have remarked, near the center of the disk it is invisible, because of insufficient contrast. But if a satellite transits over a dark portion of the planet it may be visible throughout the transit. At opposition, it is sometimes possible to see the satellite in transit projected upon its shadow on the disk of the planet. At times, the shadows have been observed to be somewhat irregular in shape, possibly when they fall on an uneven cloud surface.

High powers on large telescopes have shown markings on the minute disks of the satellites. These markings are difficult and delicate, and the amateur must consider himself lucky to pick up a vague spot or two on the disk of Ganymede; this can be done at times with an 8-inch reflector of good quality. Perhaps the best time to look for markings is when the satellite is in transit, as the lowered contrast between the planet, in the background, and the satellite may assist one's eye to detect the markings. Excellent seeing conditions and high powers (350x or more) are usually required for success.

(To be continued)

D. P. AVIGLIANO
2600 E. Orange Grove Ave.
Pasadena 8, Calif.

DATA FOR JUPITER'S GALILEAN SATELLITES

Satellite	*Name*	*Diam., miles*	*Mean mag.*	*Synodic period of revolution*	*Aids to identification*
I	Io	2,320	5.5	$1^d\ 18^h\ 28^m\ 36^s$	Most rapid motion around Jupiter; straw colored
II	Europa	1,960	5.7	$3^d\ 13^h\ 17^m\ 54^s$	Smallest of the four; white
III	Ganymede	3,200	5.1	$7^d\ 3^h\ 59^m\ 36^s$	Brightest; rosy orange
IV	Callisto	3,220	6.3	$16^d\ 18^h\ 5^m\ 7^s$	Largest orbit of the four; steel-gray color

SOME PHENOMENA OF JUPITER'S SATELLITES

IN THE morning skies of late summer and early fall, a relatively unusual phenomenon may be observed by those who watch the Galilean moons of Jupiter through small telescopes. Satellite **II**, Europa, will reappear from eclipse in the shadow of the planet for some minutes before it disappears in occultation behind the ball of the planet itself.

This occurs 16 times, first on August 18th at 14:52 UT, and last on October 10th at 22:12. The longest period of visibility of the satellite under these conditions is 16 minutes and takes place on September 16th, unfortunately while Jupiter is below the horizon for observers in the United States. The best times to see the phenomenon from the eastern part of the country are on the mornings of August 29th, September 5th, September 30th, and October 7th. These dates occur in pairs of one week, a period that is characteristic of configurations of the inner three of the bright satellites.

Of the other bright moons, **I** is so close to Jupiter that it can never be seen between eclipse and occultation. Satellite **III** can be so seen every year, while **IV** is so far from the planet that much of the time it misses eclipse and occultation altogether. When the inclination of the satellite orbits to the line between sun and planet is small enough so that eclipses of **IV** do occur, circumstances often favor occultations as well. Then the great distance of this moon from the primary makes it a common event to see the moon between eclipse and occultation.

The most favorable condition for observing any of the Jovian satellites under these circumstances is that Jupiter be at quadrature. As the diagram opposite shows, the angle between the sun and earth as seen from Jupiter is then a maximum. Quadrature occurs on September 18, 1953. A further requirement in the case of **II** is that the satellite orbit be as "opened out" as possible (similar to the case of the maximum inclination of Saturn's rings to the line of sight). This took place most recently in November, 1952. Accordingly, Jupiter **II** was visible between eclipse and occultation in 1952 and in the evening sky early this year.

When Jupiter is an evening planet, occultation of each satellite precedes eclipse, and it is occasionally possible to observe **II** a few minutes after reappearance from occultation before disappearance by eclipse. This will last happen in late winter and early spring of 1954 before the orbits become too nearly parallel to the line between earth and planet. The maximum period of visibility of **II** between occultation and eclipse in 1954 will be only six minutes.

A corresponding relation between transits of each satellite and its shadow occurs when the moon passes in front of Jupiter's disk. During the seasons that a given satellite can be observed between eclipse and occultation, it is generally impossible to see the satellite and its shadow projected simultaneously on the face of the planet.

Times of all these phenomena are tabulated in the **American Ephemeris and Nautical Almanac,** and many interesting details can be gleaned from a study of the tables. For Jupiter **II,** predicted times for eclipses and occultations discussed in this article are given here. Times are in Universal time. Ec and EcR are eclipse disappearance and reappearance, respectively; Oc and OcR refer to occultation disappearance and reappearance, respectively.

September 5, 6:55 Ec, 9:20 EcR, 9:33 Oc, 11:59 OcR. **12,** 9:30 Ec, 11:54 EcR, 12:10 Oc, 14:35 OcR. **15,** 22:47 Ec. **16,** 1:12 EcR, 1:28 Oc, 3:53 OcR. **19,** 12:04 Ec, 14:29 EcR, 14:45 Oc, 17:10 OcR. **23,** 1:22 Ec, 3:46 EcR, 4:01 Oc, 6:26 OcR. **30,** 3:56 Ec, 6:21 EcR, 6:32 Oc, 8:58 OcR. **October 7,** 6:30 Ec, 8:55 EcR, 9:01 Oc, 11:27 OcR.

PAUL W. STEVENS
2322 Westfall Rd.
Rochester 18, N. Y.

JUPITER'S SATELLITES

Jupiter's four bright moons have the positions shown below for the Universal time given. The motion of each satellite is from the dot to the number designating it. Transits of satellites over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. The chart is from the **American Ephemeris and Nautical Almanac.**

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, and the result is your standard time on the day preceding the Greenwich date shown.

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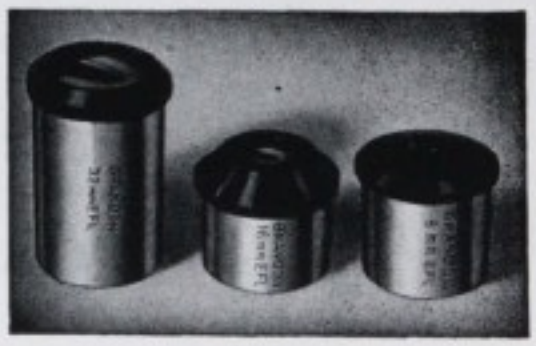

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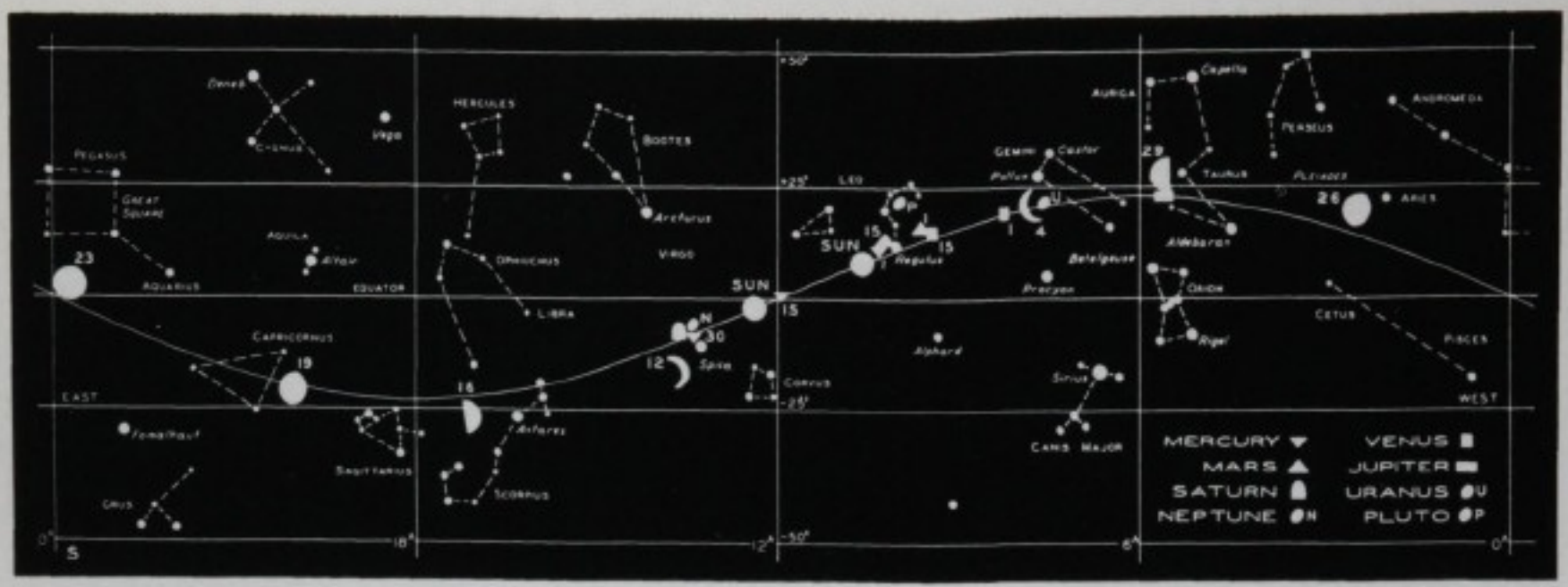
State	City	Organization	Time	Meeting Place	Communicate With
ARIZONA	Phoenix	*Phoenix Obs. Ass'n.	7:30, 1st, 3rd Tue.	Private homes	R. W. Smith, Jr., 6635 N. Central Ave.
CALIFORNIA	Fresno	Central Val. A.S.	7:45, 2nd Mon.	Fresno Coll., Homes	Elizabeth Dean, 409 Shields (4)
	Kentfield	*Marin Am. Ast.	8:00, 4th Fri.	Marin College	V. S. Yoder, 48 Mercury Av., Mill Valley
	Long Beach	†*Excelsior Tel. Club	7:30, 3rd Fri.	Art Center	T. R. Cave, Jr., 265 Roswell Ave. (3)
	Los Angeles	L.A.A.S.	7:45, 2nd Tue.	Griffith Obs.	G. Carroll, 7114 Summitrose St., Tujunga
	Oakland	*Eastbay A.S.	8:00, 1st Sat.	Chabot Obs.	Mary Grissom, 79 Bayo Vista (11)
	Palo Alto	*Peninsula A.S.	7:30, 1st Fri.	Community Center	H. W. Milner, 350 Tennyson Ave.
	Redlands	*Redlands A.S.	7:30, Tues.	Univ. of Redlands	Miss R. Schweikert, 111 Prospect Dr.
	Sacramento	*Sac. Val. A.S.	8:00, 1st Tue., bi-mon.	Sacramento College	Mrs. E. Champ, 3816 Sacramento Blvd. (17)
	San Diego	Ast. Soc. of S.D.	7:30, 1st Wed.	504 Electric Bldg.	W. T. Skilling, 3140 Sixth Ave.
	San Diego	A.T.M. Ast. Club	7:30, 2nd, 4th Mon.	3121 Hawthorn St.	Al Nelson, 3121 Hawthorn St.
	San Francisco	*S.F. Am. Ast'mers	8:00, 1st Wed.	Randall Junior Mus.	H. A. Wallace, 2925A Jackson St.
	Stockton	*Stockton A.S.	8:00, 2nd Mon.	Stockton College, C-3	Mrs. Virginia M. Craig, 2518 W. Inman (4)
COLORADO	Denver	†*Denver A.S.	8:00, 2nd, 4th Fri.	Chamberlin Obs.	John Boatright, 1400 S. Clayton, RA-0375
CONNECTICUT	Middletown	*Centr. Conn. A.A.	8:00, 1st Tue.	Van Vleck Obs.	Walter Fellows, Middle Haddam
	New Haven	†A.S. of New Haven	8:00, 4th Sat.	320 York St.	Mrs. Helen Velardi, 437 Wash., N'th Haven
	Norwalk	*Perkin-Elmer AA&TM	5:00, 1st, 3rd Wed.	Perkin-Elmer plant	J. Vrabel, Bob White Lane, Wilton
	So. Norwalk	†Fairfield Co. A.S.	8:00, Alt. Fri.	Private homes	Goldie L. Grantham, 58 Bouton St.
	Stamford	Stam. Museum A.A.	8:00, 3rd Fri.	Stamford Museum	R. F. Ives, Post Rd. East, Darien
DIST. COL.	Washington	†Nat'l. Cap. Ast'mers	8:00, 1st Sat.	Comm. Dept. Audit.	Mrs.G.R.Wright,202PipingRk.Dr.,Silv.Spr.,Md.
FLORIDA	Daytona Beach	D. B. Stargazers	8:00, Alt. Mon.	165 N. Halifax Ave.	Wm. T. Thomas, 105 N. Halifax
	Jacksonville	†*J.A.A.C.	8:00, 1st, 3rd Mon.	Private homes	E. L. Rowland, Jr., 442 St. James Bldg.
	Key West	†Key West A.C.	8:00, 1st Wed.	Private homes	J. M. Martin, 1605 United St.
	Miami	†*South'n Cross A.S.	7:30, 3rd Mon.	Central School	A. P. Smith, Jr., 426 S.W. 26 Rd.
	Miami Springs	†*Gulfstream A.A.	8:00, 4th Fri.	Boys Club, 2805 SW32Av.	L. G. Pardue, 641 Falcon, 88-5434
	Patrick AFB	Banana River A.S.	8:00, 2nd Wed.	Civilian Personnel Bldg.	Lt. R. W. Edelen, Box 669, Patrick AFB
	Pensacola	†Pensacola A.A.C.	7:30, 3rd Mon.	Private homes	Frank Dachille, 1781 E. Baars St.
GEORGIA	Atlanta	†*Atlanta A.C.	7:30, 2nd Fri.	Agnes Scott College	W. H. Close, 225 Forkner Dr., Decatur
ILLINOIS	Chicago	†*Burnham A.S.	4:00, 2nd Sun.	Adler Planetarium	J. A. Anderer, 7929 S. Loomis Blvd. (20)
	Geneva	*Fox Valley A.S.	8:00, 1st Tue.	Geneva City Hall	Joseph Zoda, 420 Fellows St.
	Moline	†*Popular A.C.	7:30, Wed.	Sky Ridge Obs.	Carl H. Gamble, 3201 Coaltown Rd.
INDIANA	Indianapolis	†*Indiana A.S.	2:15, 1st Sun.	Riley Library	Clark B. Hicks, 305 Ruckle St.
	South Bend	St. Jos. Valley Ast.	8:00, 1st Mon.	Hotel La Salle	Miss I. DeBruycker, 1023 S. Union, Mishawaka
KANSAS	Wichita	†*Wichita A.S.	8:00, 1st Wed.	214 East High Sch.	S. S. Whitehead, 2322 E. Douglas, 62-6642
KENTUCKY	Louisville	†L'ville A.S.	8:00, 1st Tue.	Univ. of Louisville	B. F. Kubaugh, 207 Sage Rd. (7)
LOUISIANA	Gretna	Gretna A.S.	7:00, Alt. Wed.	Private homes	John A. Gunther, 209 Newton St.
	Lake Charles	Lake Charles A.A.C.	7:30, 2nd Tue.	Ass'n. Commerce Bldg.	Norman G. Lore, 532 Alamo St.
	New Orleans	A.S. of N.O.	8:00, Last Wed.	Cunningham Obs.	Dr. J. Adair Lyon, 1210 Broadway
MAINE	Portland	†A.S. of Maine	8:00, 2nd Fri.	Private homes	H. Harris, 27 Victory Ave., S. Portland
MASSACHUSETTS	Cambridge	†*Bond A.C.	8:00, 1st Thu.	Harvard Obs.	R. Smith, 519 Quincy Shore Dr., No. Quincy 71
	Cambridge	†*A.T.M.s of Boston	8:00, 2nd Thu.	Harvard Obs.	John Patterson, 142 Elgin, Newton Centre 59
	Cambridge	*M.I.T. A.S.	7:30, Alt. Wed.	Mass. Inst. Tech.	R. L. White, Bx. 262, 3 Ames St.
	Springfield	†*S'field Stars	8:00, 2nd Wed.	Private homes	J. E. Welch, 107 Low'r B'verly Hills, W. S'field
	Worcester	†*Aldrich A.S.	7:30, 1st, 3rd Tue.	Mus. Natural Hist.	W. C. Lovell, 24 Courtland (2), 3-1559
MICHIGAN	Ann Arbor	†Ann Arbor A.A.A.	7:30, 2nd Mon.	U. of Mich. Obs.	Stewart W. Taylor, 1106 Birk Ave.
	Battle Creek	†B. C. Ast. Club	8:00, 2nd Fri.	Kingman Museum	Mrs. W. V. Eichenlaub, 47 Everett St.
	Detroit	†*Detroit A.S.	2:30, 2nd Sun.	Wayne U., State Hall	E. R. Phelps, Wayne University
	Kalamazoo	†Kalamazoo A.A.A.	8:00, Sat.	Private homes	Mrs. G. Negrevski, 2218 Amherst, 31482
	Lansing	†*Lansing A.A.	8:00, Fri.	Private homes	Edward H. Carlson, 2111 Grant St. (10)
	Pontiac	†*Pon.-N.W. Det. A.A.	3:00, 3rd Sun.	Cranbrook Inst.	G. Carhart, 40 Hadsell Dr., FE 2-9980
MINNESOTA	Minneapolis	M'polis A.C.	7:30, 1st, 3rd Wed.	Public Library	Jane Simmer, 2406 Clinton Ave. S.
	St. Paul	†*St. Paul Tel. Club	7:30, 2nd, 4th Wed.	Macalester Coll.	Mrs. R. E. English, 1283 Sargent Av.
MISSOURI	Fayette	†*Central Mo. A.A.	7:30, 3rd Sat.	Morrison Obs.	R. C. Maag, 816½ S. Mass., Sedalia
	Kansas City	†*A.C. of Kans. City	8:00, 4th Sat.	Private homes	Mrs. Laura Kinsey, 4604 Jefferson (2)
	St. Louis	†*St. Louis A.A.S	8:00, 3rd or 4th Fri.	Inst. of Tech., St. L. U.	S. O'Byrne, 501 E. Pacific, Webster Groves 19
NEVADA	Reno	A.S. of Nev.	8:00, 4th Wed.	Univ. of Nevada	E. W. Harris, University of Nevada
NEW JERSEY	Caldwell	West Essex A.A.	8:00, 2nd Mon.	Caldwell Mun. Bldg.	Walter J. Adams, 18 Thomas St.
	Jersey City	†Revere Boys Club	7:15, Mon., Tue.	Gregory Mem. Obs.	Enos F. Jones, 339 Wayne St.
	Roselle Park	†A.A.S. of Union Co.	....., 4th Fri.	Boro Hall	Mrs. R. N. Bochau, 236 Normandy Vill., Union
	Rutherford	A.S. of Rutherford	8:00, 1st Thu.	YMCA	W. B. Savary, 78 W. Pierrepont Ave.
	Teaneck	†Bergen Co. A.S.	8:30, 2nd Wed.	Obs., 107 Cranford Pl.	J. M. Stofan, 332 Herrick
NEW MEXICO	Las Cruces	†*A.S. of L.C.	....., 1st Sat.	Private homes	C. W. Tombaugh, 636 S. Alameda
	Roswell	*Pecos Val. S&TC.	7:30, 2nd Fri.	Cha. of Comm.	Dr. R.R. Boyce, Rt. 2, Bx. 163A
NEW YORK	Buffalo	†*Buffalo A.A.	7:30, 1st Wed.	Mus. of Science	Dr. F. S. Jones, 83 Briarcliffe, Cheektowaga (25)
	Corning	Corning A.C.	8:00, 1st, 3rd Mon.	Corning Glass Center	W. R. Redmond, 119 E. 2nd St.
	Gloversville	†*A.C. of Fulton Co.	....	.....	L. R. Ogden, 60 W. Pine St.
	New York	*A.A.A.	8:00, 1st Wed.	Amer. Mus. Nat. Hist.	G. V. Plachy, Hayden Plan., TR 3-1300
	New York	†Junior A.C.	8:00, 3rd Fri.	Amer. Mus. Nat. Hist.	J. Rothschild, Hayden Plan., TR 3-1300
	Rochester	†Rochester A.C.	8:00, Alt. Fri.	Rochester Museum	Peggy Lagen, 34 S. Goodman St. (7)
	Schenectady	†*S'tady A.C.	7:30, 3rd Mon.	Nott Terrace H.S.	C. E. Johnson, 102 State St.
	Troy	*Renss. Ap. Soc.	7:30, Alt. Tue.	Sage Lab., R.P.I.	Dr. Robert Fleischer, R.P.I.
	Utica	†*Utica Am. Ast'mers	7:30, 4th Tue.	Proctor Inst.	John Zimm, 239 Thieme Pl.
	Wantagh	Long Island A.S.	8:00, Sat.	Private homes	A. R. Luechinger, Seaford Ave., 1571
N. CAROLINA	Greensboro	†*Greensboro A.C.	8:00, 2nd Wed.	Woman's Coll., U.N.C.	Mrs. J. Bradshaw, Guilford College, N.C.
	Raleigh	†Astronomical Soc.	....., 1st, 3rd Thu.	N. C. State Coll.	Richard C. Davis, Sch. of Textiles
	Winston-Salem	†*Forsyth A.S.	7:30, Last Fri.	Private homes	Kenneth Shepherd, 1339 W. 4th St.
NORTH DAKOTA	Grand Forks	*Red River A.C.	8:00, 2nd, 4th Mon.	City Hall	L. G. Peck, 2101 1st Av. North
OHIO	Akron	*A.C. of Akron	8:00, Last Fri.	St. Peter's Epis. Church	Mrs. R. J. Couts, 878 Kennebec Ave. (5)
	Cincinnati	*Cin. A.A.	8:00, Various days	Cincinnati Obs.	Robert Berkmeier, 2432 Ohio Ave.
	Cincinnati	*Cin. A.S.	8:00, 3rd Wed.	5556 Raceview Ave.	John Dann, 3318 Felicity Dr. (11)
	Cleveland	†Cleveland A.S.	8:00, Fri.	Warner & Swasey Obs.	Mrs. A. Townhill, Warner & Swasey Obs.
	Columbus	*Columbus A.S.	8:00, 2nd Sat.	McMillin Obs.	Miss R. A. Charlton, 1361 E. 22 Ave. (11)
	Dayton	A.T.M.s of Dayton	Eve., 3rd Sat.	Private homes	F. E. Sutter, RR 7, Box 253A (9)
	Lorain-Elyria	*Black River A.S.	7:30, 2nd Tue.	Lorain YMCA	Louis Rick, Box 231, Lorain
	Marietta	Marietta A.S.	Irregular	Cisler Terrace	Miss L. E. Cisler, Cisler Terrace
	Toledo	Toledo Ast. Club	....., 3rd Tue.	Univ. of Toledo Obs.	E. D. Edenburn, 4124 Commonwealth Ave.
	Warren	Mahoning Val. A.S.	8:00, Thu.	Private homes	S. A. Hoynos, 1574 Sheridan, NE, 25034
	Youngstown	*Y'town A.C.	7:30, 1st Fri.	Homestead Pk. Pav'n.	F. W. Hartenstein, 905 Brentwood
OKLAHOMA	Tulsa	†*Tulsa A.S.	7:30, 1st Sat.	Private homes	R. L. Frossard, 4218 E. 25th Ave.
OREGON	Portland	†*Portland A.S.	8:00, 1st Mon.	Planetarium	H. J. Carruthers, 427 S. E. 61 Ave.
	Portland	†A.T.M. & Observers	8:00, 2nd Tue.	Private homes	Miss M. Edgar, 1626 S.E. Neholem (2)
PENNSYLVANIA	Beaver	†*Beaver Co. A.A.A.	8:00, 4th Tue.	Com'y Bldg., Tamaqui	Mrs. R. T. LaCaric, Box 463, Baden
	Millvale	A.A.A. Shaler T'ship	8:00, 3rd Fri.	Cherry City Fire House	Cliff Raible, Rebecca Sq. (9)
	Philadelphia	†A.A. of F.I.	8:00, 3rd Fri.	Franklin Institute	Edwin F. Bailey, LO 4-3600
	Philadelphia	†*Rittenhouse A.S.	8:00, 2nd Fri.	Franklin Institute	John Streeter, LO 4-3600
	Pittsburgh	†*A.A.A. of P'burgh	8:00, 2nd Fri.	Buhl Planetarium	Mary Bureik, 315 Moore Av. (10)
	Pottstown	Pottstown A.A.C.	7:30, Fri.	Public Library	W. E. Schultz, Public Library
RHODE ISLAND	Providence	Skyscrapers, Inc.	8:00, Mon. or Wed.	Ladd Observatory	Ladd Obs., Brown U., Jackson 1-5680
TENNESSEE	Chattanooga	†*Barnard A.S.	8:00, 3rd Fri.	Jones Observatory	A. H. Jones, 411 W. 21st St., 5-1646
	Nashville	*Barnard A.S.	7:30, 2nd Thu.	Vanderbilt Univ.	Miss J. Saffer, 446 Humphrey St. (10)
TEXAS	Dallas	†Texas A.S.	8:00, 4th Mon.	Various auditoriums	E. M. Brewer, 5218 Morningside, U6-3894
	Ft. Worth	†*Ft. Worth A.S.	8:00, 4th Fri.	Texas Christian U.	A. W. Mount, 4326 Birchman
	Port Arthur	†*Port Arthur A.C.	7:30, 2nd Thu.	5228 Fifth St.	F. T. Newton, 5213 Fifth St., 2-4807



MOON PHASES AND DISTANCE

New moon	September 8,	7:47
First quarter	September 16,	9:49
Full moon	September 23,	4:15
Last quarter	September 29,	21:51
New moon	October 8,	0:40

	September		Distance	Diameter
Apogee	9,	16h	252,600 mi.	29′ 23″
Perigee	23,	4h	221,700 mi.	33′ 29″
	October			
Apogee	6,	18h	252,600 mi.	29′ 23″

OCCULTATION PREDICTIONS

September 25-26 **Epsilon Arietis** m 4.6 2:56.5 +21-09.2, 18, Em: **G** 9:00.7 −0.9 +2.0 221; **H** 8:12.1 ... ... 177; **I** 8:50.3 −0.8 +2.0 229.

September 26-27 **23 Tauri** 4.2, 3:43.5 +23-48.2, 19, Im: **A** 2:07.7 +0.6 +2.1 30; **B** 2:14.8 +0.7 +2.3 23; **D** 2:15.0 +0.9 +2.4 18. Em: **A** 2:48.3 −0.5 +0.8 293; **B** 2:50.0 −0.7 +0.7 302; **C** 2:43.6 −0.4 +0.7 292; **D** 2:45.3 −0.6 +0.4 308.

September 26-27 **27 Tauri m** 3.8, 3:46.4 +23-54.7, 19, Im: **A** 3:07.8 0.0 +1.8 55; **B** 3:13.6 +0.1 +2.0 48; **C** 3:02.1 +0.2 +1.7 56; **D** 3:11.1 +0.3 +2.0 45; **E** 3:09.2 +0.6 +1.9 37. Em: **A** 4:05.1 −0.7 +1.3 266; **B** 4:08.2 −0.7 +1.2 274; **C** 3:57.8 −0.5 +1.3 265; **D** 4:02.1 −0.6 +1.1 279; **E** 3:52.7 −0.4 +0.8 287.

September 26-27 **Eta Tauri** 3.0, 3:44.7 +23-57.7, 19, Im: **A** 2:46.9 +1.2 +3.4 6; **C** 2:40.8 +1.2 +3.1 9. Em: **A** 3:10.8 −1.5 −0.3 316; **C** 3:05.7 −1.2 −0.3 314.

September 26-27 **28 Tauri** 5.2, 3:46.4 +23-59.7, 19, Em: **A** 4:04.8 −1.0 +0.9 284; **B** 4:06.1 −1.1 +0.7 294; **C** 3:57.5 −0.8 +0.9 283; **D** 3:58.9 −1.0 +0.6 299; **E** 3:47.2 −0.9 0.0 312.

September 28-29 **139 Tauri** 4.9, 5:55.1 +25-57.0, 21, Em: **A** 7:30.4 −1.7 −0.2 301; **B** 7:26.7 −1.8 −0.9 315; **C** 7:22.8 −1.6 +0.2 293; **D** 7:17.8 −1.7 −0.7 315; **E** 7:01.8 −1.5 −0.7 318; **F** 6:55.1 −0.9 +0.2 297.

For standard stations in the United States and Canada, for stars of magnitude 5.0 or brighter, data from the **American Ephemeris** and the **British Nautical Almanac** are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. **Lo**, lat. **L**) within 200 or 300 miles of a standard station (long. **LoS**, lat. **LS**). Multiply **a** by the difference in longitude (**Lo** — **LoS**), and multiply **b** by the difference in latitude (**L** — **LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

A	+72°.5,	+42°.5	**E**	+91°.0,	+40°.9
B	+73°.6,	+45°.6	**F**	+98°.0,	+31°.0
C	+77°.1,	+38°.9	**G**	+114°.0,	+50°.9
D	+79°.4,	+43°.7	**H**	+120°.0,	+36°.0
			I	+123°.1,	+49°.5

THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Moon. The harvest moon on September 22-23 will be the brightest moon of this year. Full phase and the closest perigee of the year coincide on the 23rd at 4:00 UT. No apparent change in brightness will be noticed all night.

Mercury will not be well situated for observing, as it remains close to the sun. Superior conjunction occurs on the 7th, the planet entering the evening sky.

Venus continues brilliant in the morning sky, rising over 2½ hours before the sun in mid-month. Its stellar magnitude is −3.4, which will remain constant for a number of months. The crescent moon will be close to Venus on the morning of the 5th, and on the 23rd the planet will pass less than ½° north of Regulus in Leo. On the 15th, the disk appears 82% illuminated and 13″ in diameter.

Earth attains heliocentric longitude 0° on September 23rd at 8:07 UT. Autumn commences north of the equator and spring in southern latitudes.

Mars is a 2nd-magnitude object rising from 1½ to two hours before the sun, as it moves eastward through Leo.

Jupiter attains western quadrature with the sun on the 18th, appearing above the eastern horizon about 10:30 p.m. local time. In eastern Taurus, the giant planet is brightening and now shines at magnitude −1.9. On the 15th, the Jovian disk is 39″ in equatorial diameter. For phenomena of Jupiter's satellites, see the special article and the chart of satellite positions.

Saturn appears low in the western evening sky, setting 1½ hours after sunset on the 10th. The planet will be of little interest until winter.

Uranus can be located with the aid of opera glasses after midnight, in Gemini about 2½° south and a little west of Kappa. The planet remains at the 6th magnitude and is moving eastward.

Neptune will be too close to the sun for observation.

E. O.

HERE AND THERE WITH AMATEURS (*continued*)

State	*City*	*Organization*	*Time*	*Meeting Place*	*Communicate With*
UTAH	Salt Lake City	†*A.S. of Utah	8:00, 2nd Fri.	City and County Bldg.	Junius J. Hayes, 1148 East 1 S.
VERMONT	Springfield	†Springfield T.M.s	6:00, 1st Sat.	Stellafane	John W. Lovely, 27 Pearl St., 535-W
VIRGINIA	Harrisonburg	Astral Society	7:30, 3rd Thu.	Vesper Heights Obs.	M. T. Brackbill, Eastern Mennonite College
	Norfolk	†*Norfolk A.S.	8:00, 2nd, 4th Thu.	Museum of Arts	A. Hustead, U.S. Weather Bureau, 21745
	Richmond	†*Richmond A.S.	8:00, 1st Tue.	Builders Exchange	J. S. Stith, 3125 Lamb Ave. (22)
WASHINGTON	Seattle	*Seattle A.A.S.	8:00, 2nd Fri.	Rainier Field House	P. J. Ritscher, 1631 N. 53 St.
	Spokane	†*A.T.M.s of Spokane	8:00, Last Fri.	Private homes	Chet Brown, W. 1117-14th
	Tacoma	Tacoma A.A.	8:00, 1st Mon.	Coll. of Puget Sd.	Dorothy E. Nicholson, 2816 N. Union Ave.
	Yakima	†*Yak. Am. Ast'mers	8:00, 2nd Mon.	Cha. of Comm. Bldg.	Edward J. Newman, 324 W. Yakima Ave.
WISCONSIN	Beloit	†Beloit A.S.	7:30, 2nd, 4th Wed.	YMCA Bldg.	K. E. Patterson, 318 Public Service Bldg.
	Madison	†Madison A.S.	8:00, 2nd Wed.	Washburn Obs.	Dr. C. M. Huffer, Washburn Obs.
	Milwaukee	†*Milw. A.S.	8:00, 2nd Mon.	Public Museum	E. A. Halbach, 2971 S. 52 St., W. Allis

DEEP-SKY WONDERS

WITH September comes a slack tide of celestial treasures. The unlimited golden sands of Sagittarius now dip into the horizon, Scutum dims in the lower altitudes, and the Northern Cross assumes at last an erect position as it prepares to slide into the western trees. Objectives stop dewing up, sweaters appear, and the early morning observer begins to watch for the cool luminous cone of the zodiacal light in the east. Only above the pole does the thin band of the Milky Way remind the watcher of winter glories some months ahead. This is the season for the last of the globular clusters that Messier catalogued. Not until June will they again cross the meridian in any numbers.

In Sagittarius, close to the edge of Capricornus, is NGC 6864, M75, lying at $20^h\ 3^m.2$, $-22°\ 4'$. Its diameter is 4'.6 and its visual magnitude about 9. It should be remembered that the total magnitude of an extended object depends greatly on the size of the telescope and the observing conditions. This cluster is receding from us at a relative velocity of *222* kilometers per second. It probably lies farther away than most globulars, for the 25 brightest stars average visually about 15th magnitude and it takes a pretty fair-sized scope to hint at resolution.

Leaving, now, the satisfactions of this distant celestial beehive, the amateur may very well scan NGC 6981, M72, at $20^h\ 50^m.7$, $-12°\ 44'$. It is 5'.1 in diameter and about magnitude 9 visually. Next turn to the famous cluster in Pegasus, NGC 7078 or M15. Its position is $21^h\ 27^m.6$, $+11°\ 57'$; its diameter is 12'.3, visual magnitude 6. No less than 66 variables stud this cluster, which is resolvable on the edges. Finally try NGC 7089, M2, of the 6th magnitude and 11'.7 in diameter, at $21^h\ 30^m.9$, $-1°\ 3'$.

WALTER SCOTT HOUSTON

COMET PONS-BROOKS

This periodic comet, observed in 1812 and in 1883-84, returns to perihelion next summer, according to the predictions by Dr. Paul Herget reported in **Sky and Telescope** for May, 1952, page 171. Miss Elizabeth Roemer has recovered this comet as a 17th-magnitude object in Draco, on photographs taken June 20th at the Lick Observatory. Her observations show that the comet will pass through perihelion on May 22, 1954, only five days earlier than Dr. Herget had predicted. At that time the comet may become visible to the naked eye.

During September, Comet Pons-Brooks will slowly brighten to the 16th magnitude as it moves southward through Hercules.

VARIABLE STAR MAXIMA

September 2, R Cassiopeiae, 235350, 6.5; 11, R Indi, 222**867**, 8.0; 17, R Phoenicis, 235**150**, 7.8; 18, R Normae, 152**849**, 7.2; 18, RS Herculis, 171723, 8.0; 24, X Monocerotis, 065**208**, 7.6; 24, T Hydrae, 085**008**, 7.7; 24, W Lyrae, 181136, 8.0; 25, T Centauri, 133**633**, 6.1; 27, S Carinae, 100**661**, 5.7; 27, R Hydrae, 132**422**, 4.6; 29, R Centauri, 140**959**, 5.9. October 4, R Octantis, 055**686**, 7.9.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

MINIMA OF ALGOL

September 1, 20:54; 4, 17:43; 7, 14:32; 10, 11:20; 13, 8:09; 16, 4:57; 19, 1:46; 21, 22:35; 24, 19:23; 27, 16:12; 30, 13:00. October 3, 9:49.

These minima predictions for Algol are taken from the 1953 **Handbook** of the Royal Astronomical Society of Canada.

PREDICTIONS OF BRIGHT MINOR PLANET POSITIONS

Massalia, *20*, 9.1. Sept. 10, 1:00.1 +6-52; 20, 0:53.3 +6-08; 30, 0:44.8 +5-12. Oct. 10, 0:35.5 +4-09; 20, 0:26.9 +3-10; 30, 0:19.9 +2-21.

Pax, 679, 9.2. Sept. 30, 2:20.5 —38-22. Oct. 10, 2:15.6 —39-42; 20, 2:08.2 —40-00; 30, 2:00.3 —39-10. Nov. 9, 1:53.8 —37-11; 19, 1:50.1 —34-05.

Interamnia, 704, 9.7. Sept. 30, 2:31.2 +39-34. Oct. 10, 2:25.2 +39-41; 20, 2:17.2 +39-18; 30, 2:08.3 +38-24. Nov. 9, 1:59.6 +37-04; 19, 1:52.5 +35-25.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1953.0) for 0h Universal time. In each case the motion of the asteroid is retrograde. Data supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

VESTA

Vesta passed opposition last month, but can be followed with binoculars of moderate power for the remainder of the year, as it decreases in magnitude from 6.5 to 7.8. The minor planet ends retrograde motion on September 30th, and is in eastern Capricornus through mid-November. Positions from the **American Ephemeris** given below may be plotted on the Skalnate Pleso **Atlas of the Heavens,** which shows stars down to the brightness of Vesta.

September 1, $21^h\ 39^m.2$ $-23°\ 11'$; **15,** $21^h\ 30^m.2$ $-23°\ 56'$; **30,** $21^h\ 26^m.7$ $-23°\ 58'$. **October 15,** $21^h\ 30^m.0$ $-23°\ 18'$; **31,** $21^h\ 40^m.0$ $-22°\ 02'$. **November 15,** $21^h\ 54^m.2$ $-20°\ 24'$; **30,** $22^h\ 11^m.8$ $-18°\ 27'$. **December 15,** $22^h\ 31^m.8$ $-16°\ 12'$; **31,** $22^h\ 54^m.9$ $-13°\ 34'$. E. O.

SUNSPOT NUMBERS

June 1, 14, 15; **2,** 26, 28; **3,** 24, 23; **4,** 35, 53; **5,** 34, 35; **6,** 34, 32; **7,** 32, 36; **8,** 34, 30; **9,** 30, 28; **10,** 28, 24; **11,** 17, 18; **12,** 7, 7; **13,** 3, 0; **14,** 18, 12; **15,** 21, 24; **16,** 25, 33; **17,** 21, 33; **18,** 18, 20; **19,** 26, 25; **20,** 29, 26; **21,** 18, 22; **22,** 17, 20; **23,** 13, 10; **24,** 12, 11; **25,** 17, 10; **26,** 13, 17; **27,** 5, 21; **28,** 4, 7; **29,** 7, 8; **30,** 6, 7. Means for June: 19.6 American; 21.2 Zurich.

Daily values of the observed mean relative sunspot numbers are given above. The first are the American numbers computed by Neal J. Heines from Solar Division observations; the second are the Zurich Observatory numbers.

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